(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) **EP 4 449 840 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
23.10.2024 Bulletin 2024/43

(21) Application number: **22910592.9**

(22) Date of filing: **28.10.2022**

(51) International Patent Classification (IPC):
A01B 69/00 *(2006.01)* ***G05D 1/02*** *(2020.01)*

(52) Cooperative Patent Classification (CPC):
A01B 69/00; G05D 1/02

(86) International application number:
PCT/JP2022/040395

(87) International publication number:
WO 2023/119871 (29.06.2023 Gazette 2023/26)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **24.12.2021 JP 2021210461**

(71) Applicant: **Kubota Corporation**
Osaka 556-8601 (JP)

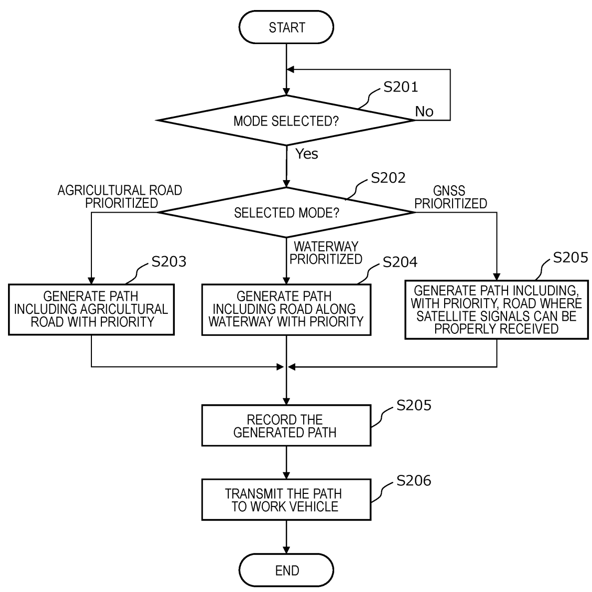
(72) Inventors:
- **MIYASHITA, Shunsuke**
  Sakai-shi, Osaka 590-0908 (JP)
- **MURATA, Yusuke**
  Sakai-shi, Osaka 590-0908 (JP)

(74) Representative: **Cabinet Beau de Loménie**
158, rue de l'Université
75340 Paris Cedex 07 (FR)

(54) ROUTE-PLANNING SYSTEM AND ROUTE-PLANNING METHOD FOR AUTOMATICALLY TRAVELING FARM MACHINE

(57) A path planning system for an agricultural machine to automatically travel inside and outside a field includes a storage device to store a map of a region including a plurality of fields and roads around the plurality of fields; and a processing unit to generate a path for the agricultural machine on the map. The map includes attribute information representing, for each of the roads, at least one of whether the road is an agricultural road, whether the road is a road along a specific feature, or whether the road is a road where satellite signals from GNSS satellites can be properly received. For generation of a path toward a field or a path from a field toward another site, the processing unit generates at least one of a path including an agricultural road with priority, a path including a road along the specific feature with priority, or a path including, with priority, a road where the satellite signals can be properly received, as the path for the agricultural machine based on the attribute information.

FIG. 14



EP 4 449 840 A1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to path planning systems and path planning methods for agricultural machines performing self-traveling.

BACKGROUND ART

[0002] Research and development has been directed to the automation of agricultural machines to be used in agricultural fields. For example, work vehicles, such as tractors, combines, and rice transplanters, which automatically travel within fields by utilizing a positioning system, e.g. , a GNSS (Global Navigation Satellite System), are coming into practical use. Research and development is also under way for work vehicles which automatically travel not only within fields, but also outside the fields.

[0003] Patent Documents 1 and 2 each disclose an example of system to cause an unmanned work vehicle to automatically travel between two fields separated from each other with a road being sandwiched therebetween.

CITATION LIST

PATENT LITERATURE

[0004]

[Patent Document 1] Japanese Laid-Open Patent Publications No. 2021-073602
[Patent Document 2] Japanese Laid-Open Patent Publications No. 2021-029218

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] The present disclosure provides systems and methods to generate preferred paths for agricultural machines performing self-traveling.

SOLUTION TO PROBLEM

[0006] A path planning system according to an illustrative embodiment of the present disclosure is for an agricultural machine to automatically travel inside and outside a field. The path planning system includes a storage device to store a map of a region including a plurality of fields and roads around the plurality of fields, and a processing unit to generate a path for the agricultural machine on the map. The map includes attribute information representing, for each of the roads, at least one of whether the road is an agricultural road, whether the road is a road along a specific feature, or whether the road is a road where satellite signals from GNSS satellites can be properly received. For generation of a path toward a field or a path from a field toward another site, the processing unit generates at least one of a path including an agricultural road with priority, a path including a road along the specific feature with priority, and a path including, with priority, a road where the satellite signals can be properly received, as the path for the agricultural machine based on the attribute information.

[0007] General or specific aspects of the present disclosure may be implemented using a device, a system, a method, an integrated circuit, a computer program, a non-transitory computer-readable storage medium, or any combination thereof. The computer-readable storage medium may be inclusive of a volatile storage medium or a non-volatile storage medium. The device may include a plurality of devices. In the case where the device includes two or more devices, the two or more devices may be disposed within a single apparatus, or divided over two or more separate apparatuses.

ADVANTAGEOUS EFFECTS OF INVENTION

[0008] According to embodiments of the present disclosure, it is possible to provide systems and methods to generate preferred paths for agricultural machines performing self-traveling.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

[FIG. **1**] FIG. **1** is a diagram providing an overview of an agriculture management system according to an illustrative embodiment of the present disclosure.
[FIG. **2**] FIG. **2** is a side view schematically showing an example of work vehicle and an example of implement that is linked to the work vehicle.
[FIG. **3**] FIG. **3** is a block diagram showing an example configuration of the work vehicle and the implement.
[FIG. **4**] FIG. **4** is a conceptual diagram showing an example of the work vehicle performing positioning based on an RTK-GNSS.
[FIG. **5**] FIG. **5** is a diagram showing an example of operational terminal and an example of operation switches disposed in a cabin.
[FIG. **6**] FIG. **6** is a block diagram showing an example of hardware configuration of a management device and a terminal device.
[FIG. **7**] FIG. **7** is a diagram schematically showing an example of the work vehicle automatically traveling along a target path inside a field.
[FIG. **8**] FIG. **8** is a flowchart showing an example operation of steering control during self-driving.
[FIG. **9A**] FIG. **9A** is a diagram showing an example of the work vehicle traveling along a target path **P.**
[FIG. **9B**] FIG. **9B** is a diagram showing an example of the work vehicle at a position which is shifted rightward from the target path **P**.
[FIG. **9C**] FIG. **9C** is a diagram showing an example of the work vehicle at a position which is shifted leftward from the target path **P**.
[FIG. **9D**] FIG. **9D** is a diagram showing an example of the work vehicle oriented in an inclined direction with respect to the target path **P**.
[FIG. **10**] FIG. **10** is a diagram schematically showing an example of state where a plurality of the work vehicles perform self-traveling inside a field and on a road outside the field.
[FIG. **11**] FIG. **11** is a diagram showing an example of setting screen displayed on the terminal device.
[FIG. **12**] FIG. **12** is a table showing an example of schedule of agricultural work created by the management device.
[FIG. **13**] FIG. **13** is a diagram showing an example of GUI displayed on a display device.
[FIG. **14**] FIG. **14** is a flowchart showing a path generation process in the example shown in FIG. **13**.
[FIG. **15**] FIG. **15** is a diagram showing another example of GUI displayed on the display device.
[FIG. **16**] FIG. **16** is a diagram showing an example of map of a region where the work vehicle is to travel.
[FIG. **17**] FIG. **17** is a diagram showing an example of path generated in the case where an "agricultural road prioritized" mode is selected.
[FIG. **18**] FIG. **18** is a diagram showing an example of path generated in the case where a "waterway prioritized" mode is selected.
[FIG. **19**] FIG. **19** is a diagram showing another example of map of a region where the work vehicle is to travel.
[FIG. **20**] FIG. **20** is a diagram showing an example of path generated in the case where a "GNSS prioritized" mode is selected.
[FIG. **21**] FIG. **21** is a diagram schematically showing an example of state where the work vehicle is traveling in the vicinity of a row of trees.
[FIG. **22A**] FIG. **22A** is a graph showing an example of reception strength of satellite signals.
[FIG. **22B**] FIG. **22B** is a graph showing another example of reception strength of satellite signals.
[FIG. **23**] FIG. **23** is a diagram showing an example of path generated by the management device in the case where a "time prioritized" mode is selected.
[FIG. **24**] FIG. **24** is a diagram showing an example of global path.
[FIG. **25**] FIG. **25** is a table showing an example of correspondence between waiting areas and fields.
[FIG. **26**] FIG. **26** is a diagram showing an example of global path generated on one working day.
[FIG. **27**] FIG. **27** is a diagram showing an example of global path and an example of local path generated in an environment where there is an obstacle.
[FIG. **28**] FIG. **28** is a flowchart showing a method for path planning and travel control.

DESCRIPTION OF EMBODIMENTS

(Definition of terms)

[0010] In the present disclosure, an "agricultural machine" refers to a machine for agricultural applications. Examples of agricultural machines include tractors, harvesters, rice transplanters, vehicles for crop management, vegetable transplanters, mowers, seeders, spreaders, and mobile robots for agriculture. Not only may a work vehicle such as a tractor function as an "agricultural machine" alone by itself, but also a combination of a work vehicle and an implement that is attached to, or towed by, the work vehicle may function as an "agricultural machine". For the ground surface inside a field, the agricultural machine performs agricultural work such as tilling, seeding, preventive pest control, manure spreading, planting of crops, or harvesting. Such agricultural work or tasks may be referred to as "groundwork", or simply as "work" or "tasks". Travel of a vehicle-type agricultural machine performed while the agricultural machine also performs agricultural work may be referred to as "tasked travel".

[0011] "Self-driving" refers to controlling the movement of an agricultural machine by the action of a controller, rather than through manual operations of a driver. An agricultural machine that performs self-driving may be referred to as a "self-driving agricultural machine" or a "robotic agricultural machine". During self-driving, not only the movement of the agricultural machine, but also the operation of agricultural work (e.g., the operation of the implement) may be controlled automatically. In the case where the agricultural machine is a vehicle- type machine, travel of the agricultural machine via self-driving will be referred to as "self - traveling". The controller may control at least one of: steering that is required in the movement of the agricultural machine, adjustment of the moving speed, or beginning and ending of a move. In the case of controlling a work vehicle having an implement attached thereto, the controller may be configured or programmed to control raising or lowering of the implement, beginning and ending of an operation of the implement, and so on. A move based on self-driving may include not only moving of an agricultural machine that goes along a predetermined path toward a destination, but also moving of an agricultural machine that follows a target of tracking. An agricultural machine that performs self -driving may also move partly based on the user’s instructions. Moreover, an agricultural machine that performs self-driving may operate not only in a self-driving mode but also in a manual driving mode, where the agricultural machine moves through manual operations of the driver. When performed not manually but through the action of a controller, the steering of an agricultural machine will be referred to as "automatic steering". A portion of, or the entirety of, the controller may reside outside the agricultural machine. Control signals, commands, data, etc., may be communicated between the agricultural machine and a controller residing outside the agricultural machine. An agricultural machine that performs self-driving may move autonomously while sensing the surrounding environment, without any person being involved in the controlling of the movement of the agricultural machine. An agricultural machine that is capable of autonomous movement is able to travel inside the field or outside the field (e.g., on roads) in an unmanned manner. During an autonomous move, operations of detecting and avoiding obstacles may be performed.

[0012] A "work plan" is data defining a plan of one or more tasks of agricultural work to be performed by an agricultural machine. The work plan may include, for example, information representing the order of the tasks of agricultural work to be performed by an agricultural machine or the field where each of the tasks of agricultural work is to be performed. The work plan may include information representing the time and the date when each of the tasks of agricultural work is to be performed. In particular, the work plan including information representing the time and the date when each of the tasks of agricultural work is to be performed is referred to as a "work schedule" or simply as a "schedule". The work schedule may include information representing the time when each task of agricultural work is to be begun and/or ended on each of working days. The work plan or the work schedule may include information representing, for each task of agricultural work, the contents of the task, the implement to be used, and/or the types and amounts of agricultural supplies to be used. As used herein, the term "agricultural supplies" refers to goods used for agricultural work to be performed by an agricultural machine. The agricultural supplies may also be referred to simply as "supplies". The agricultural supplies may include goods consumed by agricultural work such as, for example, agricultural chemicals, fertilizers, seeds, or seedlings. The work plan may be created by a processing unit communicating with the agricultural machine to manage the agricultural machine or a processing unit mounted on the agricultural machine. The processing unit can create a work plan based on, for example, information input by the user (agricultural business executive, agricultural worker, etc.) manipulating a terminal device. In this specification, the processing unit communicating with the agricultural machine to manage the agricultural machine will be referred to as a "management device" . The management device may manage agricultural work of a plurality agricultural machines. In this case, the management device may create a work plan including information on each task of agricultural work to be performed by each of the plurality of agricultural machines. The work plan may be downloaded to each of the agricultural machines and stored in a storage device in each of the agricultural machines . In order to perform the scheduled agricultural work in accordance with the work plan, each agricultural machine can automatically move to a field and perform the agricultural work.

[0013] An "environment map" is data representing, with a predetermined coordinate system, the position or the region of an object existing in the environment where the agricultural machine moves. The environment map may be referred to simply as a "map" or "map data". The coordinate system defining the environment map is, for example, a world coordinate system such as a geographic coordinate system fixed to the globe. Regarding the object existing in the environment, the environment map may include information other than the position (e.g., attribute information or other types of information). The "environment map" encompasses various type of maps such as a point cloud map and a lattice map. Data on a local map or a partial map that is generated or processed in a process of constructing the environment map is also referred to as a "map" or "map data".

[0014] An "agricultural road" is a road used mainly for agriculture. An "agricultural road" is not limited to a road paved with asphalt, and encompasses unpaved roads covered with soil, gravel or the like. An "agricultural road" encompasses roads (including private roads) on which only vehicle-type agricultural machines (e.g., work vehicles such as tractors, etc.) are allowed to travel and roads on which general vehicles (automobiles, trucks, buses, etc.) are also allowed to travel. The work vehicles may automatically travel on a general road in addition to an agricultural road. The "general road" is a road maintained for traffic of general vehicles.

[0015] A "feature" refers to an object existing on the earth. Examples of features include waterways, grass, trees, roads, fields, ditches, rivers, bridges, forests, mountains, rocks, buildings, railroad tracks, and the like. Borders, names of places, names of buildings, names of fields, names of railroad lines and the like, which do not exist in the real world, are not encompassed in the "feature" according to the present disclosure.

[0016] A "GNSS satellite" refers to an artificial satellite in the Global Navigation Satellite System (GNSS). GNSS is the general term for satellite positioning systems such as GPS (Global Positioning System), QZSS (Quasi-Zenith Satellite System), GLONASS, Galileo, and BeiDou. A GNSS satellite is a satellite in such a positioning system. A signal transmitted from a GNSS satellite is referred to as a "satellite signal". A "GNSS receiver" is a device to receive radio waves transmitted from a plurality of satellites in the GNSS and perform positioning based on a signal superposed on the radio waves. "GNSS data" is data output from the GNSS receiver. The GNSS data may be generated in a predetermined format such as, for example, the NMEA-0183 format. The GNSS data may include, for example, information representing a receiving state of the satellite signal received from each of the satellites. The GNSS data may include, for example, the identification number, the angle of elevation, the azimuth angle, and a value representing the reception strength of each of the satellites from which the satellite signals are received. The reception strength is a numerical value representing the strength of each received satellite signal. The reception strength may be expressed by a value such as, for example, the carrier to noise density ratio (C/NO). The GNSS data may include positional information on the GNSS receiver or the agricultural machine, the positional information being calculated based on a plurality of received satellite signals. The positional information may be expressed by, for example, the latitude, the longitude and the altitude from the mean sea level. The GNSS data may further include information representing the reliability of the positional information.

[0017] The expression "satellite signals can be properly received" indicates that the satellite signals can be received stably such that the reliability of the positioning is not significantly lowered. A state where satellite signals cannot be received in a normal state may be expressed as a "reception failure of satellite signals" occurring. The "reception failure of satellite signals" is a state where the reliability of the positioning is lowered as compared with the normal receiving state, due to deterioration in the receiving state of the satellite signals. A reception failure may occur in the case where, for example, the number of detected satellites is small (e.g., three or less), the reception strength of each satellite signal is low, or multi-path is occurring. Whether or not a reception failure is occurring may be determined based on, for example, information on the satellites that is included in the GNSS data. It can be determined whether a reception failure is occurring based on, for example, the value of the reception strength of each of the satellites included in the GNSS data or the value of DOP (Dilution of Precision) representing the state of positional arrangement of the satellites.

[0018] A "global path" is data on a path connecting a departure point to a target point of an automatic movement of the agricultural machine, and is generated by a processing unit performing path planning. Generation of such a global path is referred to as "global path planning". In the following description, the global path will be referred to also as a "target path" or simply as a "path" . The global path may be defined by, for example, coordinate values of a plurality of points which the agricultural machine is to pass. Such a point that the agricultural machine is to pass is referred as a "waypoint", and a line segment connecting waypoints adjacent to each other is referred to as a "link".

[0019] A "local path" is a path by which the agricultural machine can avoid an obstacle, and is consecutively generated while the agricultural machine is automatically moving along the global path. Generation of such a local path is referred to as "local path planning" . The local path is consecutively generated based on data acquired by one or more sensing devices included in the agricultural machine, during a movement of the agricultural machine. The local path may be def ined by a plurality of waypoints along a portion of the global path. Note that in the case where there is an obstacle in the vicinity of the global path, the waypoints may be set so as to detour around the obstacle. The length of a link between the waypoints on the local path is shorter than the length of a link between the waypoints on the global path. The device generating the local path may be the same as, or different from, the device generating the global path. For example, the management device managing the agricultural work to be performed by the agricultural machine may generate the global path, whereas the controller mounted on the agricultural machine may generate the local path. In this case, a combination of the management device and the controller functions as a "processing unit" performing the path planning. The controller of the agricultural machine may function as a processing unit performing both of global path planning and local path planning.

[0020] A "repository" is a site provided for storage of an agricultural machine. The repository may be, for example, a site managed by a user of an agricultural machine or a site run jointly by a plurality of users of agricultural machines.

The repository may be, for example, a site saved for storage of an agricultural machine, such as a warehouse, a barn or a parking area at a house or an office of the user (agricultural worker, etc.). The position of the repository may be previously registered and recorded in a storage device.

[0021] A "waiting area" is a site provided for an agricultural machine to wait while the agricultural machine does not perform agricultural work. One or more waiting areas may be provided in an environment where an agricultural machine performs self-driving. The above-described repository is an example of the waiting area. The waiting area may be managed or used jointly by a plurality of users. The waiting area may be, for example, a warehouse, a garage, a barn, a parking area, or any other facilities. The waiting area may be a warehouse, a barn, a garage or a parking area at a house or an office of an agricultural worker different from the user of the agricultural machine. A plurality of waiting areas may be scattered in the environment where an agricultural machine moves. In the waiting area, work such as replacement or maintenance of a portion or an implement of the agricultural machine, or supplement of supplies, may be performed. In this case, parts, tools or supplies necessary for the work may be provided in the waiting area.

(Embodiments)

[0022] Hereinafter, embodiments of the present disclosure will be described. Note, however, that unnecessarily detailed descriptions may be omitted. For example, detailed descriptions on what is well known in the art or redundant descriptions on what is substantially the same configuration may be omitted. This is to avoid lengthy description, and facilitate the understanding of those skilled in the art. The accompanying drawings and the following description, which are provided by the present inventors so that those skilled in the art can sufficiently understand the present disclosure, are not intended to limit the scope of the claims. In the following description, elements having identical or similar functions are denoted by identical reference numerals.

[0023] The following embodiments are only exemplary, and the techniques according to the present disclosure are not limited to the following embodiments. For example, numerical values, shapes, materials, steps, orders of steps, layout of a display screen, etc., which are indicated in the following embodiments are only exemplary, and admit of various modifications so long as it makes technological sense. Any one implementation may be combined with another so long as it makes technological sense to do so.

[0024] Hereinafter, embodiments in which techniques according to the present disclosure are applied to a work vehicle, such as a tractor, which is an example of agricultural machine, will be mainly described. The techniques according to the present disclosure are also applicable to other types of agricultural machines in addition to the work vehicle such as a tractor.

[0025] FIG. 1 is a diagram providing an overview of an agriculture management system according to an illustrative embodiment of the present disclosure. The agriculture management system shown in FIG. 1 includes a work vehicle 100, a terminal device **400**, and a management device **600**. The terminal device **400** is a computer used by a user performing remote monitoring of the work vehicle **100.** The management device **600** is a computer managed by a business operator running the agriculture management system. The work vehicle **100**, the terminal device **400** and the management device **600** can communicate with each other via the network **80**. FIG. **1** shows one work vehicle **100**, but the agriculture management system may include a plurality of the work vehicles or any other agricultural machine.

[0026] The work vehicle **100** according to the present embodiment is a tractor. The work vehicle **100** can have an implement attached to its rear and/or its front. While performing agricultural work in accordance with a particular type of implement, the work vehicle **100** is able to travel inside a field. The work vehicle **100** may travel inside the field or outside the field with no implement being attached thereto.

[0027] The work vehicle **100** has a self-driving function. In other words, the work vehicle **100** can travel by the action of a controller, rather than manually. The controller according to the present embodiment is provided inside the work vehicle **100**, and is able to control both the speed and steering of the work vehicle **100**. The work vehicle **100** can perform self-traveling outside the field (e.g., on roads) as well as inside the field.

[0028] The work vehicle **100** includes a device usable for positioning or localization, such as a GNSS receiver or an LiDAR sensor. Based on the position of the work vehicle **100** and information on a target path generated by the management device **600**, the controller of the work vehicle **100** causes the work vehicle **100** to automatically travel. In addition to controlling the travel of the work vehicle **100**, the controller also controls the operation of the implement. As a result, while to automatically travel inside the field, the work vehicle **100** is able to perform agricultural work by using the implement. In addition, the work vehicle **100** is able to automatically travel along the target path on a road outside the field (e.g. , an agricultural road or a general road) . In the case of performing self - traveling on a road outside the field, the work vehicle **100** travels while generating, along the target path, a local path along which the work vehicle **100** can avoid an obstacle, based on data output from a sensing device such as a camera or a LiDAR sensor. Inside the field, the work vehicle **100** may travel while generating a local path in substantially the same manner as described above, or may perform an operation of traveling along the target path without generating a local path and halting when an obstacle is detected.

[0029] The management device **600** is a computer to manage the agricultural work performed by the work vehicle **100**. The management device **600** may be, for example, a server computer that performs centralized management on information regarding the field on the cloud and supports agriculture by use of the data on the cloud. The management device **600** can, for example, create a work plan for the work vehicle **100** and generate a target path for the work vehicle **100** in accordance with the work plan. Alternatively, the management device **600** may generate a target path for the work vehicle **100** in response to a manipulation performed by the user by use of the terminal device **400**. Hereinafter, unless otherwise specified, the target path (i.e., global path) for the work vehicle **100** to be generated by the management device **600** will be referred to simply as a "path".

[0030] The management device **600** includes a storage device and a processing unit. The storage device stores a map of a region including a plurality of fields and roads around the fields. The processing unit generates a path for the work vehicle **100** on the map. The map includes attribute information representing, for each of the roads, at least one of: whether the road is an agricultural road; whether the road is a road along a specific feature such as a waterway or a river; and whether the road is a road where satellite signals from GNSS satellites can be properly received. For generation of a path toward a field or a path from a field toward another site, the processing unit generates at least one of a path including an agricultural road with priority, a path including a road along a specific feature with priority, or a path including, with priority, a road where satellite signals from GNSS satellites can be properly received. The processing unit generates at least one of these paths as the path for the work vehicle **100** based on the attribute information. As a result of such a process, a preferred path for self -traveling of the work vehicle **100** can be generated as described below in detail.

[0031] The management device **600** generates a target path inside the field and a target path outside the field by different methods from each other. The management device **600** generates a target path inside the field based on information regarding the field. For example, the management device **600** can generate a target path inside the field based on various types of previously registered information such as the outer shape of the field, the area size of the field, the position of the entrance/exit of the field, the width of the work vehicle **100**, the width of the implement, the contents of the work, the types of crops to be grown, the region where the crops are to be grown, the growing states of the crops, and the interval between rows or ridges of the crops. The management device **600** generates a target path inside the field based on, for example, information input by the user by use of the terminal device **400** or any other device. The management device **600** generates a path inside the field such that the path covers, for example, the entirety of a work area where the work is to be performed. Meanwhile, the management device **600** generates a path outside the field in accordance with the work plan or the user's instructions. For example, the management device **600** can generate a target path outside the field based on various types of information such as the order of tasks of agricultural work indicated by the work plan, the position of the field where each task of agricultural work is to be performed, the position of the entrance/exit of the field, the time when each task of agricultural work is to begin and/or end, the attribute information on each road recorded on the map, the state of the road surface, the state of weather or the traffic state. The management device **600** may generate a target path based on information representing the path or the waypoints specified by the user manipulating the terminal device **400**, without relying on the work plan.

[0032] The management device **600** may be configured to generate a path including a specific type of road with priority, in accordance with a priority item selected by the user by manipulation of the terminal device **400**. The specific type of road may be, for example, an agricultural road, a road along a specific feature such as a waterway, a road where satellite signals from GNSS satellites can be properly received, or a road by which the destination site can be reached within a shortest time period. A method for generating a path with such a specific type of road being prioritized will be described below in detail.

[0033] In addition, the management device **600** may generate or edit an environment map based on data collected by the work vehicle **100** or any other movable body by use of the sensing device such as a LiDAR sensor. The management device **600** transmits data on the work plan, the target path and the environment map thus generated to the work vehicle **100**. The work vehicle **100** automatically moves and performs agricultural work based on the data.

[0034] The global path planning and the generation (or editing) of the environment map may be performed by any other device than the management device **600**. For example, the controller of the work vehicle **100** may perform global path planning, or the generation or editing of the environment map.

[0035] The terminal device **400** is a computer that is used by a user who is at a remote place from the work vehicle **100**. The terminal device **400** shown in FIG. **1** is a laptop computer, but the terminal device **400** is not limited to this. The terminal device **400** may be a stationary computer such as a desktop PC (personal computer), or a mobile terminal such as a smartphone or a tablet computer. The terminal device **400** may be used to perform remote monitoring of the work vehicle **100** or remote-manipulate the work vehicle **100**. For example, the terminal device **400** can display, on a display screen thereof , a video captured by one or more cameras included in the work vehicle **100**. The user can watch the video to check the state of the surroundings of the work vehicle **100** and instruct the work vehicle **100** to halt or begin traveling. The terminal device **400** can also display, on the display screen thereof, a setting screen allowing the user to input information necessary to create a work plan (e.g., a schedule of each task of agricultural work) for the work vehicle

100. When the user inputs necessary information to the setting screen and performs a manipulation to transmit the information, the terminal device **400** transmits the input information to the management device **600.** The management device **600** creates a work plan based on the information. The terminal device **400** may also be used to register one or more fields where the work vehicle **100** is to perform the agricultural work, the repository for the work vehicle **100**, and one or more waiting areas where the work vehicle **100** is to temporarily wait. The terminal device **400** may further have a function of displaying, on a display screen thereof, a setting screen allowing the user to input information necessary to set a target path.

[0036] Hereinafter, a configuration and an operation of the system according to the present embodiment will be described in more detail.

[1. Configuration]

[0037] FIG. **2** is a side view schematically showing an example of the work vehicle **100** and an example of implement **300** linked to the work vehicle **100**. The work vehicle **100** according to the present embodiment can operate both in a manual driving mode and a self-driving mode. In the self-driving mode, the work vehicle **100** is able to perform unmanned travel. The work vehicle **100** can perform self-driving both inside a field and outside the field.

[0038] As shown in FIG. **2**, the work vehicle **100** includes a vehicle body **101,** a prime mover (engine) **102**, and a transmission **103**. On the vehicle body **101**, wheels **104** with tires and a cabin **105** are provided. The wheels **104** include a pair of front wheels **104F** and a pair of rear wheels **104R.** Inside the cabin **105**, a driver's seat **107**, a steering device **106**, an operational terminal **200**, and switches for manipulation are provided. In the case where the work vehicle **100** performs tasked travel inside the field, the front wheels **104F** and/or the rear wheels **104R** may be replaced with wheels (crawlers) provided with continuous tracks, instead of being wheels provided with tires.

[0039] The work vehicle **100** includes a plurality of sensing devices sensing the surroundings of the work vehicle **100.** In the example shown in FIG. **2**, the sensing devices include a plurality of cameras **120**, a LiDAR sensor **140**, and a plurality of obstacle sensors **130**.

[0040] The cameras **120** may be provided at the front/rear/right/left of the work vehicle **100**, for example. The cameras **120** image the surrounding environment of the work vehicle **100** and generate image data. The images acquired by the cameras **120** may be transmitted to the terminal device **400**, which is responsible for remote monitoring. The images may be used to monitor the work vehicle **100** during unmanned driving. The cameras **120** may also be used to generate images to allow the work vehicle **100**, traveling on a road outside the field (an agricultural road or a general road), to recognize objects, obstacles, white lines, road signs, traffic signs or the like in the surroundings of the work vehicle **100**.

[0041] The LiDAR sensor **140** in the example shown in FIG. **2** is disposed on a bottom portion of a front surface of the vehicle body **101**. The LiDAR sensor **140** may be disposed at any other position. While the work vehicle **100** is traveling mainly outside the field, the LiDAR sensor **140** repeatedly outputs sensor data representing the distance and the direction between an object existing in the surrounding environment thereof and each of measurement points, or a two-dimensional or three-dimensional coordinate values of each of the measurement points . The sensor data output from the LiDAR sensor **140** is processed by the controller of the work vehicle **100**. The controller can perform localization of the work vehicle **100** by matching the sensor data against the environment map. The controller can further detect an object such as an obstacle existing in the surroundings of the work vehicle **100** based on the sensor data, and generate, along the global path, a local path along which the work vehicle **100** needs to actually proceed. The controller can utilize an algorithm such as, for example, SLAM (Simultaneous Localization and Mapping) to generate or edit an environment map. The work vehicle **100** may include a plurality of LiDAR sensors disposed at different positions with different orientations.

[0042] The plurality of obstacle sensors **130** shown in FIG. **2** are provided at the front and the rear of the cabin **105**. The obstacle sensors **130** may be disposed at other positions. For example, one or more obstacle sensors **130** may be disposed at any position at the sides, the front or the rear of the vehicle body **101.** The obstacle sensors **130** may include, for example, a laser scanner or an ultrasonic sonar. The obstacle sensors **130** may be used to detect obstacles in the surroundings of the work vehicle **100** during self-traveling to cause the work vehicle **100** to halt or detour around the obstacles. The LiDAR sensor **140** may be used as one of the obstacle sensors **130**.

[0043] The work vehicle **100** further includes a GNSS unit **110**. The GNSS unit **110** includes a GNSS receiver. The GNSS receiver may include an antenna to receive a signal (s) from a GNSS satellite (s) and a processor to calculate the position of the work vehicle **100** based on the signal (s) received by the antenna. The GNSS unit **110** receives satellite signals transmitted from the plurality of GNSS satellites, and performs positioning based on the satellite signals. Although the GNSS unit **110** according to the present embodiment is disposed above the cabin **105**, it may be disposed at any other position.

[0044] The GNSS unit **110** may include an inertial measurement unit (IMU). Signals from the IMU can be used to complement position data. The IMU can measure a tilt or a small motion of the work vehicle **100**. The data acquired by the IMU can be used to complement the position data based on the satellite signals, so as to improve the performance of positioning.

[0045] The controller of the work vehicle **100** may utilize, for positioning, the sensing data acquired by the sensing devices such as the cameras **120** or the LIDAR sensor **140**, in addition to the positioning results provided by the GNSS unit **110**. In the case where objects serving as characteristic points exist in the environment that is traveled by the work vehicle **100**, as in the case of an agricultural road, a forest road, a general road or an orchard, the position and the orientation of the work vehicle **100** can be estimated with a high accuracy based on data that is acquired by the cameras **120** or the LiDAR sensor **140** and on an environment map that is previously stored in the storage device. By correcting or complementing position data based on the satellite signals using the data acquired by the cameras **120** or the LiDAR sensor **140**, it becomes possible to identify the position of the work vehicle **100** with a higher accuracy.

[0046] The prime mover **102** may be a diesel engine, for example. Instead of a diesel engine, an electric motor may be used. The transmission **103** can change the propulsion and the moving speed of the work vehicle **100** through a speed changing mechanism. The transmission **103** can also switch between forward travel and backward travel of the work vehicle **100**.

[0047] The steering device **106** includes a steering wheel, a steering shaft connected to the steering wheel, and a power steering device to assist in the steering by the steering wheel. The front wheels **104F** are the steered wheels, such that changing their angle of turn (also referred to as "steering angle") can cause a change in the traveling direction of the work vehicle **100**. The steering angle of the front wheels **104F** can be changed by manipulating the steering wheel. The power steering device includes a hydraulic device or an electric motor to supply an assisting force to change the steering angle of the front wheels **104F**. When automatic steering is performed, under the control of the controller disposed in the work vehicle **100**, the steering angle may be automatically adjusted by the power of the hydraulic device or the electric motor.

[0048] A linkage device **108** is provided at the rear of the vehicle body **101**. The linkage device **108** includes, e.g., a three-point linkage (also referred to as a "three-point link" or a "three-point hitch"), a PTO (Power Take Off) shaft, a universal joint, and a communication cable. The linkage device **108** allows the implement **300** to be attached to, or detached from, the work vehicle **100**. The linkage device **108** is able to raise or lower the three-point link with a hydraulic device, for example, thus changing the position and/or attitude of the implement **300**. Moreover, motive power can be sent from the work vehicle **100** to the implement **300** via the universal joint. While towing the implement **300**, the work vehicle **100** allows the implement **300** to perform a predetermined task. The linkage device may be provided frontward of the vehicle body **101**. In that case, the implement can be connected frontward of the work vehicle **100**.

[0049] Although the implement **300** shown in FIG. **2** is a rotary tiller, the implement **300** is not limited to a rotary tiller. For example, any arbitrary implement such as a seeder, a spreader, a transplanter, a mower, a rake implement, a baler, a harvester, a sprayer, or a harrow, can be connected to the work vehicle **100** for use.

[0050] The work vehicle **100** shown in FIG. **2** can be driven by human driving; alternatively, it may only support unmanned driving. In that case, component elements which are only required for human driving, e.g., the cabin **105**, the steering device **106**, and the driver's seat **107** do not need to be provided in the work vehicle **100**. An unmanned work vehicle **100** can travel via autonomous driving, or by remote operation by a user.

[0051] FIG. **3** is a block diagram showing an example configuration of the work vehicle **100** and the implement **300**. The work vehicle **100** and the implement **300** can communicate with each other via a communication cable that is included in the linkage device **108**. The work vehicle **100** is able to communicate with the terminal device **400** and the management device **600** via the network **80**.

[0052] In addition to the GNSS unit **110**, the cameras **120**, the obstacle sensors **130**, the LiDAR sensor **140** and the operational terminal **200**, the work vehicle **100** in the example of FIG. **3** includes sensors **150** to detect the operating status of the work vehicle **100**, a control system **160**, a communication device **190**, operation switches **210**, a buzzer **220**, and a drive device **240.** These component elements are communicably connected to each other via a bus. The GNSS unit **110** includes a GNSS receiver **111**, an RTK receiver **112**, an inertial measurement unit (IMU) **115**, and a processing circuit **116**. The sensors **150** include a steering wheel sensor **152**, an angle-of-turn sensor **154**, and an axle sensor **156.** The control system **160** includes a storage device **170** and a controller **180**. The controller **180** includes a plurality of electronic control units (ECU) **181** to **186**. The implement **300** includes a drive device **340**, a controller **380**, and a communication device **390**. Note that FIG. **3** shows component elements which are relatively closely related to the operations of self-driving by the work vehicle **100**, while other components are omitted from illustration.

[0053] The GNSS receiver **111** in the GNSS unit **110** receives satellite signals transmitted from the plurality of GNSS satellites and generates GNSS data based on the satellite signals . The GNSS data is generated in a predetermined format such as, for example, the NMEA-0183 format. The GNSS data may include, for example, the identification number, the angle of elevation, the azimuth angle, and a value representing the reception strength of each of the satellites from which the satellite signals are received. The reception strength may be expressed by a value of, for example, the carrier to noise density ratio (C/NO) . The GNSS data may also include positional information on the work vehicle **100** calculated based on a plurality of received satellite signals, and information representing the reliability of the positional information. The positional information may be expressed by, for example, the latitude, the longitude and the altitude from the mean sea level. The reliability of the positional information may be expressed by, for example, the DOP value representing the state of positional arrangement of the satellites.

[0054] The GNSS unit **110** shown in FIG. **3** performs positioning of the work vehicle **100** by utilizing an RTK (Real Time Kinematic)-GNSS. FIG. **4** is a conceptual diagram showing an example of the work vehicle **100** performing positioning based on the RTK-GNSS. In the positioning based on the RTK-GNSS, not only satellite signals transmitted from a plurality of GNSS satellites **50**, but also a correction signal that is transmitted from a reference station **60** is used. The reference station **60** may be disposed near the field where the work vehicle **100** performs tasked travel (e.g. , at a position within 10 km of the work vehicle **100**). The reference station **60** generates a correction signal of, for example, an RTCM format based on the satellite signals received from the plurality of GNSS satellites **50**, and transmits the correction signal to the GNSS unit **110**. The RTK receiver **112**, which includes an antenna and a modem, receives the correction signal transmitted from the reference station **60**. Based on the correction signal, the processing circuit **116** of the GNSS unit **110** corrects the results of the positioning performed by use of the GNSS receiver **111**. Use of the RTK-GNSS enables positioning with an accuracy on the order of several centimeters of errors, for example. Positional information including latitude, longitude, and altitude information is acquired through the highly accurate positioning by the RTK-GNSS. The GNSS unit **110** calculates the position of the work vehicle **100** as frequently as, for example, one to ten times per second.

[0055] Note that the positioning method is not limited to being performed by use of an RTK-GNSS; any arbitrary positioning method (e.g. , an interferometric positioning method or a relative positioning method) that provides positional information with the necessary accuracy can be used. For example, positioning may be performed by utilizing a VRS (Virtual Reference Station) or a DGPS (Differential Global Positioning System). In the case where positional information with the necessary accuracy can be obtained without the use of the correction signal transmitted from the reference station **60**, positional information may be generated without using the correction signal. In that case, the GNSS unit **110** does not need to include the RTK receiver **112**.

[0056] Even in the case where the RTK-GNSS is used, at a site where the correction signal from the reference station **60** cannot be acquired (e.g., on a road far from the field), the position of the work vehicle **100** is estimated by another method with no use of the signal from the RTK receiver **112**. For example, the position of the work vehicle **100** may be estimated by matching the data output from the LiDAR sensor **140** and/or the cameras **120** against a highly accurate environment map.

[0057] The GNSS unit **110** according to the present embodiment further includes the IMU **115**. The IMU **115** may include a 3-axis accelerometer and a 3-axis gyroscope. The IMU **115** may include a direction sensor such as a 3-axis geomagnetic sensor. The IMU **115** functions as a motion sensor which can output signals representing parameters such as acceleration, velocity, displacement, and attitude of the work vehicle **100**. Based not only on the satellite signals and the correction signal but also on a signal that is output from the IMU **115**, the processing circuit **116** can estimate the position and orientation of the work vehicle **100** with a higher accuracy. The signal that is output from the IMU **115** may be used for the correction or complementation of the position that is calculated based on the satellite signals and the correction signal. The IMU **115** outputs a signal more frequently than the GNSS receiver **111**. Utilizing this signal that is output highly frequently, the processing circuit **116** allows the position and orientation of the work vehicle **100** to be measured more frequently (e.g. , about 10 Hz or above) . Instead of the IMU **115**, a 3-axis accelerometer and a 3-axis gyroscope may be separately provided. The IMU **115** may be provided as a separate device from the GNSS unit **110**.

[0058] The cameras **120** are imagers that image the surrounding environment of the work vehicle **100**. Each of the cameras **120** includes an image sensor such as a CCD (Charge Coupled Device) or a CMOS (Complementary Metal Oxide Semiconductor), for example. In addition, each camera **120** may include an optical system including one or more lenses and a signal processing circuit. During travel of the work vehicle **100**, the cameras **120** image the surrounding environment of the work vehicle **100**, and generate image data (e.g. , motion picture data) . The cameras **120** are able to capture motion pictures at a frame rate of 3 frames/second (fps: frames per second) or greater, for example. The images generated by the cameras **120** may be used by a remote supervisor to check the surrounding environment of the work vehicle **100** with the terminal device **400**, for example. The images generated by the cameras **120** may also be used for the purpose of positioning and/or detection of obstacles. As shown in FIG. **2**, the plurality of cameras **120** may be provided at different positions on the work vehicle **100**, or a single camera **120** may be provided. A visible camera(s) to generate visible light images and an infrared camera (s) to generate infrared images may be separately provided. Both of a visible camera(s) and an infrared camera(s) may be provided as cameras for generating images for monitoring purposes. The infrared camera (s) may also be used for detection of obstacles at nighttime.

[0059] The obstacle sensors **130** detect objects existing in the surroundings of the work vehicle **100**. Each of the obstacle sensors **130** may include a laser scanner or an ultrasonic sonar, for example. When an object exists at a position within a predetermined distance from one of the obstacle sensors **130**, the obstacle sensor **130** outputs a signal indicating the presence of the obstacle. The plurality of obstacle sensors **130** may be provided at different positions on the work vehicle **100**. For example, a plurality of laser scanners and a plurality of ultrasonic sonars may be disposed at different positions on the work vehicle **100**. Providing such a great number of obstacle sensors **130** can reduce blind spots in monitoring obstacles in the surroundings of the work vehicle **100**.

[0060] The steering wheel sensor **152** measures the angle of rotation of the steering wheel of the work vehicle **100**. The angle - of - turn sensor **154** measures the angle of turn of the front wheels **104F**, which are the steered wheels. Measurement values by the steering wheel sensor **152** and the angle - of - turn sensor **154** are used for steering control by the controller **180**.

[0061] The axle sensor **156** measures the rotational speed, i.e., the number of revolutions per unit time, of an axle that is connected to the wheels **104**. The axle sensor **156** may be a sensor including a magnetoresistive element (MR), a Hall generator, or an electromagnetic pickup, for example. The axle sensor **156** outputs a numerical value indicating the number of revolutions per minute (unit: rpm) of the axle, for example. The axle sensor **156** is used to measure the speed of the work vehicle **100**.

[0062] The drive device **240** includes various types of devices required to cause the work vehicle **100** to travel and to drive the implement **300**; for example, the prime mover **102**, the transmission **103**, the steering device **106**, the linkage device **108** and the like described above. The prime mover **102** may include an internal combustion engine such as, for example, a diesel engine. The drive device **240** may include an electric motor for traction instead of, or in addition to, the internal combustion engine.

[0063] The buzzer **220** is an audio output device to present an alarm sound to alert the user of an abnormality. For example, the buzzer **220** may present an alarm sound when an obstacle is detected during self-driving. The buzzer **220** is controlled by the controller **180**.

[0064] The storage device **170** includes one or more storage mediums such as a flash memory or a magnetic disc. The storage device **170** stores various data that is generated by the GNSS unit **110**, the cameras **120**, the obstacle sensors **130**, the LiDAR sensor **140**, the sensors **150**, and the controller **180.** The data that is stored by the storage device **170** may include map data on the environment where the work vehicle **100** travels (environment map) and data on a global path (target path) for self-driving. The environment map includes information on a plurality of fields where the work vehicle **100** performs agricultural work and roads around the fields. The environment map and the target path may be generated by a processing unit (i.e., a processor) in the management device **600**. The controller **180** according to the present embodiment may have a function of generating or editing an environment map and a target path. The controller **180** can edit the environment map and the target path, acquired from the management device **160**, in accordance with the environment where the work vehicle **100** travels. The storage device **170** also stores data on a work plan received by the communication device **190** from the management device **600**. The work plan includes information on a plurality of tasks of agricultural work to be performed by the work vehicle **100** over a plurality of working days. The work plan may be, for example, data on a work schedule including information on the time when the work vehicle **100** is scheduled to perform each task of agricultural work on each of the working days. The storage device **170** also stores a computer program(s) to cause each of the ECUs in the controller **180** to perform various operations described below. Such a computer program(s) may be provided to the work vehicle **100** via a storage medium (e.g., a semiconductor memory, an optical disc, etc.) or through telecommunication lines (e.g., the Internet). Such a computer program(s) may be marketed as commercial software.

[0065] The controller **180** includes the plurality of ECUs. The plurality of ECUs include, for example, the ECU **181** for speed control, the ECU **182** for steering control, the ECU **183** for implement control, the ECU **184** for self-driving control, the ECU **185** for path generation, and the ECU **186** for map generation.

[0066] The ECU **181** controls the prime mover **102**, the transmission **103** and brakes included in the drive device **240**, thus controlling the speed of the work vehicle **100**.

[0067] The ECU **182** controls the hydraulic device or the electric motor included in the steering device **106** based on a measurement value of the steering wheel sensor **152**, thus controlling the steering of the work vehicle **100**.

[0068] In order to cause the implement **300** to perform a desired operation, the ECU **183** controls the operations of the three-point link, the PTO shaft and the like that are included in the linkage device **108**. Also, the ECU **183** generates a signal to control the operation of the implement **300**, and transmits this signal from the communication device **190** to the implement **300.**

[0069] Based on data output from the GNSS unit **110**, the cameras **120**, the obstacle sensors **130**, the LiDAR sensor **140** and the sensors **150**, the ECU **184** performs computation and control for achieving self-driving. For example, the ECU **184** specifies the position of the work vehicle **100** based on the data output from at least one of the GNSS unit **110**, the cameras **120**, or the LiDAR sensor **140**. Inside the field, the ECU **184** may determine the position of the work vehicle **100** based only on the data output from the GNSS unit **110**. The ECU **184** may estimate or correct the position of the work vehicle **100** based on the data acquired by the cameras **120** or the LiDAR sensor **140**. Use of the data acquired by the cameras **120** or the LiDAR sensor **140** allows the accuracy of the positioning to be further improved. Outside the field, the ECU **184** estimates the position of the work vehicle **100** by use of the data output from the LiDAR sensor **140** or the cameras **120**. For example, the ECU **184** may estimate the position of the work vehicle **100** by matching the data output from the LiDAR sensor **140** or the cameras **120** against the environment map. During self -driving, the ECU **184** performs computation necessary for the work vehicle **100** to travel along a target path or a local path, based on the estimated position of the work vehicle **100**. The ECU **184** sends the ECU **181** a command to change the speed, and sends the ECU **182** a command to change the steering angle. In response to the command to change the speed, the ECU **181** controls the prime mover **102**, the transmission **103** or the brakes to change the speed of the work vehicle **100**. In response to the command to change the steering angle, the ECU **182** controls the steering device **106** to change the steering angle.

[0070] While the work vehicle **100** is traveling along the target path, the ECU **185** consecutively generates a local path along which the work vehicle **100** can avoid an obstacle. During travel of the work vehicle **100**, the ECU **185** recognizes an obstacle existing in the surroundings of the work vehicle **100** based on the data output from the cameras **120**, the obstacle sensors **130** and the LiDAR sensor **140**. The ECU **185** generates a local path such that the work vehicle **100** avoids the recognized obstacle.

[0071] The ECU **185** may have a function of performing global path planning instead of the management device **160**. In this case, the ECU **185** determines a destination of the work vehicle **100** based on the work plan stored in the storage device **170**, and determines a target path from a beginning point to a target point of the movement of the work vehicle **100**. For example, the ECU **185** can generate, as the target path, a path by which the work vehicle **100** can arrive at the destination within the shortest time period, based on the environment map stored in the storage device **170** and including information on the roads. Alternatively, the ECU **185** may generate a path including, with priority, a specific type of road (e.g. , an agricultural road, a road along a specific feature such as a waterway, a road where satellite signals from GNSS satellites are receivable in a satisfactory manner, or the like) , as the target path based on the attribute information on each of the roads included in the environment map.

[0072] The ECU **186** generates or edits a map of the environment where the work vehicle **100** travels. In the present embodiment, an environment map generated by an external device such as the management device **600** is transmitted to the work vehicle **100** and recorded in the storage device **170.** Instead, the ECU **186** can generate or edit an environment map. Hereinafter, an operation in a case where the ECU **186** generates an environment map will be described. An environment map may be generated based on sensor data output from the LiDAR sensor **140**. For generating an environment map, the ECU **186** consecutively generates three-dimensional point cloud data based on the sensor data output from the LiDAR sensor **140** while the work vehicle **100** is traveling. The ECU **186** can generate an environment map by connecting the point cloud data consecutively generated by use of an algorithm such as, for example, SLAM. The environment map generated in this manner is a highly accurate three-dimensional map, and may be used for localization performed by the ECU **184**. Based on this three-dimensional map, a two-dimensional map usable for the global path planning may be generated. In this specification, the three-dimensional map that is used for the localization and the two-dimensional map that is used for the global path planning will be both referred to as an "environment map". The ECU **186** can further edit the map by adding, to the map, various types of attribute information on a feature (e.g., a waterway, a river, grass, a tree, etc.), the type of the road (e.g., whether the road is an agricultural road), the state of the road surface, how easily the road is passable, or the like that is recognized based on the data output from the cameras **120** or the LiDAR sensor **140**.

[0073] Through the actions of these ECUs, the controller **180** realizes self-driving. During self-driving, the controller **180** controls the drive device **240** based on the measured or estimated position of the work vehicle **100** and on the generated path. As a result, the controller **180** can cause the work vehicle **100** to travel along the target path.

[0074] The plurality of ECUs included in the controller **180** can communicate with each other in accordance with a vehicle bus standard such as, for example, a CAN (Controller Area Network) . Instead of the CAN, faster communication methods such as Automotive Ethernet (registered trademark) may be used. Although the ECUs **181** to **186** are illustrated as individual blocks in FIG. **3**, the function of each of the ECU **181** to **186** may be implemented by a plurality of ECUs. Alternatively, an onboard computer that integrates the functions of at least some of the ECUs **181** to **186** may be provided. The controller **180** may include ECUs other than the ECUs **181** to **186**, and any number of ECUs may be provided in accordance with functionality. Each ECU includes a processing circuit including one or more processors.

[0075] The communication device **190** is a device including a circuit communicating with the implement **300**, the terminal device **400** and the management device **600**. The communication device **190** includes circuitry to perform exchanges of signals complying with an ISOBUS standard such as ISOBUS-TIM, for example, between itself and the communication device **390** of the implement **300**. This allows the implement **300** to perform a desired operation, or allows information to be acquired from the implement **300**. The communication device **190** may further include an antenna and a communication circuit to exchange signals via the network **80** with communication devices of the terminal device **400** and the management device **600**. The network **80** may include a 3G, 4G, 5G, or any other cellular mobile communications network and the Internet, for example. The communication device **190** may have a function of communicating with a mobile terminal that is used by a supervisor who is situated near the work vehicle **100**. With such a mobile terminal, communication may be performed based on any arbitrary wireless communication standard, e.g., Wi-Fi (registered trademark), 3G, 4G, 5G or any other cellular mobile communication standard, or Bluetooth (registered trademark).

[0076] The operational terminal **200** is a terminal for the user to perform a manipulation related to the travel of the work vehicle **100** and the operation of the implement **300**, and is also referred to as a virtual terminal (VT) . The operational terminal **200** may include a display device such as a touch screen panel, and/or one or more buttons. The display device may be a display such as a liquid crystal display or an organic light-emitting diode (OLED) display, for example. By manipulating the operational terminal **200**, the user can perform various manipulations, such as, for example, switching ON/OFF the self-driving mode, recording or editing an environment map, setting a target path, and switching ON/OFF the implement **300**. At least a portion of these manipulations may also be realized by manipulating the operation switches **210**. The operational terminal **200** may be configured so as to be detachable from the work vehicle **100.** A user who is at a remote place from the work vehicle **100** may manipulate the detached operational terminal **200** to control the operation of the work vehicle **100.** Instead of the operational terminal **200**, the user may manipulate a computer on which necessary application software is installed, for example, the terminal device **400**, to control the operation of the work vehicle **100**.

[0077] FIG. **5** is a diagram showing an example of the operational terminal **200** and an example of the operation switches **210** both provided in the cabin **105**. In the cabin **105**, the switches **210**, including a plurality of switches that are manipulable to the user, are disposed. The operation switches **210** may include, for example, a switch to select the gear shift as to a main gear shift or a range gear shift, a switch to switch between a self-driving mode and a manual driving mode, a switch to switch between forward travel and backward travel, a switch to raise or lower the implement **300**, and the like. In the case where the work vehicle **100** only performs unmanned driving and lacks human driving functionality, the work vehicle **100** does not need to include the operation switches **210**.

[0078] The drive device **340** in the implement **300** shown in FIG. **3** performs operations necessary for the implement **300** to perform predetermined work. The drive device **340** includes a device suitable for uses of the implement **300**, for example, a hydraulic device, an electric motor, a pump or the like. The controller **380** controls the operation of the drive device **340.** In response to a signal that is transmitted from the work vehicle **100** via the communication device **390**, the controller **380** causes the drive device **340** to perform various operations. Moreover, a signal that is in accordance with the state of the implement **300** can be transmitted from the communication device **390** to the work vehicle **100**.

[0079] Now, a configuration of the management device **600** and the terminal device **400** will be described with reference to FIG. **6**. FIG. **6** is a block diagram showing an example of schematic hardware configuration of the management device **600** and the terminal device **400**.

[0080] The management device **600** includes a storage device **650**, a processor **660**, a ROM (Read Only Memory) **670**, a RAM (Random Access Memory) **680**, and a communication device **690**. These component elements are communicably connected to each other via a bus. The management device **600** may function as a cloud server to manage the schedule of the agricultural work to be performed by the work vehicle **100** in a field and support agriculture by use of the data managed by the management device **600** itself . The user can input information necessary to create a work plan by use of the terminal device **400** and upload the information to the management device **600** via the network **80**. The management device **600** can create a schedule of agricultural work, that is, a work plan based on the information. The management device **600** can further generate or edit an environment map and perform global path planning for the work vehicle **100**. The environment map may be distributed from a computer external to the management device **600**.

[0081] The communication device **690** is a communication module to communicate with the work vehicle **100** and the terminal device **400** via the network **80**. The communication device **690** can perform wired communication in compliance with communication standards such as, for example, IEEE1394 (registered trademark) or Ethernet (registered trademark). The communication device **690** may perform wireless communication in compliance with Bluetooth (registered trademark) or Wi-Fi, or cellular mobile communication based on 3G, 4G, 5G or any other cellular mobile communication standard.

[0082] The processor **660** may be, for example, a semiconductor integrated circuit including a central processing unit (CPU). The processor **660** may be realized by a microprocessor or a microcontroller. Alternatively, the processor **660** may be realized by an FPGA (Field Programmable Gate Array), a GPU (Graphics Processing Unit), an ASIC (Application Specific Integrated Circuit) or an ASSP (Application Specific Standard Product) each including a CPU, or a combination of two or more selected from these circuits. The processor **660** consecutively executes a computer program, describing commands to execute at least one process, stored in the ROM **670** and thus realizes a desired process.

[0083] The ROM **670** is, for example, a writable memory (e.g. , PROM), a rewritable memory (e.g. , flash memory) or a memory which can only be read from but cannot be written to. The ROM **670** stores a program to control operations of the processor **660**. The ROM **670** does not need to be a single storage medium, and may be an assembly of a plurality of storage mediums. A portion of the assembly of the plurality of storage memories may be a detachable memory.

[0084] The RAM **680** provides a work area in which the control program stored in the ROM **670** is once developed at the time of boot. The RAM **680** does not need to be a single storage medium, and may be an assembly of a plurality of storage mediums.

[0085] The storage device **650** mainly functions as a storage for a database. The storage device **650** may be, for example, a magnetic storage device or a semiconductor storage device. An example of the magnetic storage device is a hard disc drive (HDD) . An example of the semiconductor storage device is a solid state drive (SSD) . The storage device **650** may be a device independent from the management device **600**. For example, the storage device **650** may be a storage device connected to the management device **600** via the network **80**, for example, a cloud storage.

[0086] The terminal device **400** includes an input device **420**, a display device **430**, a storage device **450**, a processor **460**, a ROM **470**, a RAM **480**, and a communication device **490.** These component elements are communicably connected to each other via a bus. The input device **420** is a device to convert an instruction from the user into data and input the data to a computer. The input device **420** may be, for example, a keyboard, a mouse or a touch panel. The display device **430** may be, for example, a liquid crystal display or an organic EL display. The processor **460**, the ROM **470**, the RAM **480**, the storage device **450** and the communication device **490** are substantially the same as the corresponding component elements described above regarding the example of the hardware configuration of the management device **600**, and will not be described in repetition.

[2. Operation]

[0087] Now, an operation of the work vehicle **100**, the terminal device **400** and the management device **600** will be described.

[2-1. Self-traveling operation]

[0088] First, an example operation of self-traveling of the work vehicle **100** will be described. The work vehicle **100** according to the present embodiment can automatically travel both inside and outside a field. Inside the field, the work vehicle **100** drives the implement **300** to perform predetermined agricultural work while traveling along a preset target path. When detecting an obstacle by the obstacle sensors **130** thereof while traveling inside the field, the work vehicle **100** halts traveling and performs operations of presenting an alarm sound from the buzzer **220**, transmitting an alert signal to the terminal device **400** and the like. Inside the field, the positioning of the work vehicle **100** is performed based mainly on data output from the GNSS unit **110**. Meanwhile, outside the field, the work vehicle **100** automatically travels along a target path set for an agricultural road or a general road outside the field. While traveling outside the field, the work vehicle **100** performs local path planning based on data acquired by the cameras **120** or the LiDAR **140**. When an obstacle is detected outside the field, the work vehicle **100** avoids the obstacle or halts at the point. Outside the field, the position of the work vehicle **100** is estimated based on data output from the LiDAR sensor **140** or the cameras **120** in addition to positioning data output from the GNSS unit **110**.

[0089] Hereinafter, an operation of the work vehicle **100** performing self - traveling inside the field will be described. An operation of the work vehicle **100** performing self-traveling outside the field and a process of global path planning and local path planning outside the field will be described later.

[0090] FIG. **7** is a diagram schematically showing an example of the work vehicle **100** to automatically travel along a target path in a field. In this example, the field includes a work area **72**, in which the work vehicle **100** performs work by using the implement **300,** and headlands **74,** which are located near outer edges of the field. The user may previously specify which regions of the field on the map would correspond to the work area **72** and the headlands **74**. The target path in this example includes a plurality of main paths **P1** parallel to each other and a plurality of turning paths **P2** interconnecting the plurality of main paths **P1**. The main paths **P1** are located in the work area **72**, whereas the turning paths **P2** are located in the headlands **74**. Although each of the main paths **P1** in FIG. **7** is illustrated as a linear path, each main path **P1** may also include a curved portion (s) . The main paths **P1** may be automatically generated by, for example, the user performing a manipulation of designating two points in the vicinity of ends of the field (points **A** and **B** in FIG. **7**) while looking at the map of the field displayed on the operational terminal **200** or the terminal device **400**. In this case, the plurality of main paths **P1** are set to be parallel to a line segment connecting the point **A** and the point **B** designated by the user, the main paths **P1** are connected to each other with the turning paths **P2,** and thus the target path inside the field is generated. Broken lines in FIG. **7** depict the working breadth of the implement **300**. The working breadth is previously set and recorded in the storage device **170**. The working breadth may be set and recorded by the user manipulating the operational terminal **200** or the terminal device **400**. Alternatively, the working breadth may be automatically recognized and recorded when the implement **300** is connected to the work vehicle **100**. The interval between the plurality of main paths **P1** may be set so as to be matched to the working breadth. The target path may be generated based on the manipulation made by the user, before self -driving is begun. The target path may be generated so as to cover the entire work area **72** in the field, for example. Along the target path shown in FIG. **7**, the work vehicle **100** automatically travels while repeating a reciprocating motion from a beginning point of work to an ending point of work. Note that the target path shown in FIG. **7** is merely an example, and the target path may be arbitrarily determined.

[0091] Now, an example control by the controller **180** during self-driving inside the field will be described.

[0092] FIG. **8** is a flowchart showing an example operation of steering control to be performed by the controller **180** during self-driving. During travel of the work vehicle **100**, the controller **180** performs automatic steering by performing the operation from steps **S121** to **S125** shown in FIG. **8**. The speed of the work vehicle **100** will be maintained at a previously-set speed, for example. First, during travel of the work vehicle **100**, the controller **180** acquires data representing the position of the work vehicle **100** that is generated by the GNSS unit **110** (step **S121**). Next, the controller

180 calculates a deviation between the position of the work vehicle **100** and the target path (step **S122**). The deviation represents the distance between the position of the work vehicle **100** and the target path at that moment. The controller **180** determines whether the calculated deviation in position exceeds the previously-set threshold or not (step **S123**). If the deviation exceeds the threshold, the controller **180** changes a control parameter of the steering device included in the drive device **240** so as to reduce the deviation, thus changing the steering angle (step **S124**). If the deviation does not exceed the threshold at step **S123**, the operation of step **S124** is omitted. At the following step **S125**, the controller **180** determines whether a command to end the operation has been received or not. The command to end the operation may be given when the user has instructed that self-driving be suspended through remote operations, or when the work vehicle **100** has arrived at the destination, for example. If the command to end the operation has not been given, the control returns to step **S121** and the controller **180** performs substantially the same operation based on a newly measured position of the work vehicle **100**. The controller **180** repeats the operation from steps **S121** to **S125** until a command to end the operation is given. The aforementioned operation is executed by the ECUs **182** and **184** in the controller **180**.

[0093] In the example shown in FIG. **8**, the controller **180** controls the drive device **240** based only on the deviation between the position of the work vehicle **100** as identified by the GNSS unit **110** and the target path. Alternatively, a deviation in terms of directions may further be considered in the control. For example, when a directional deviation exceeds a previously-set threshold, where the directional deviation is an angle difference between the orientation of the work vehicle **100** as identified by the GNSS unit **110** and the direction of the target path, the controller **180** may change the control parameter of the steering device of the drive device **240** (e.g., steering angle) in accordance with the deviation.

[0094] Hereinafter, with reference to FIGS. **9A** to **9D**, an example of steering control by the controller **180** will be described more specifically.

[0095] FIG. **9A** is a diagram showing an example of the work vehicle **100** traveling along a target path **P**. FIG. **9B** is a diagram showing an example of the work vehicle **100** at a position which is shifted rightward from the target path **P**. FIG. **9C** is a diagram showing an example of the work vehicle **100** at a position which is shifted leftward from the target path **P**. FIG. **9D** is a diagram showing an example of the work vehicle **100** oriented in an inclined direction with respect to the target path **P**. In these figures, the pose, i.e., the position and orientation, of the work vehicle **100** as measured by the GNSS unit **110** is expressed as $r(x,y,\theta)$. Herein, (x,y) are coordinates representing the position of a reference point on the work vehicle **100** in an XY coordinate system, which is a two-dimensional coordinate system fixed to the globe. In the examples shown in FIGS. **9A** to **9D**, the reference point on the work vehicle **100** is at a position, on the cabin, where a GNSS antenna is disposed, but the reference point may be at any arbitrary position. θ is an angle representing the measured orientation of the work vehicle **100**. Although the target path **P** is shown parallel to the Y axis in the examples illustrated in these figures, the target path **P** may not necessarily be parallel to the Y axis, in general.

[0096] As shown in FIG. **9A**, in the case where the position and orientation of the work vehicle **100** are not deviated from the target path **P**, the controller **180** maintains the steering angle and speed of the work vehicle **100** without changing them.

[0097] As shown in FIG. **9B**, when the position of the work vehicle **100** is shifted rightward from the target path **P**, the controller **180** changes the steering angle so that the traveling direction of the work vehicle **100** will be inclined leftward, thus bringing the work vehicle **100** closer to the path **P.** At this point, not only the steering angle but also the speed may be changed. The magnitude of the steering angle may be adjusted in accordance with the magnitude of a positional deviation Δx, for example.

[0098] As shown in FIG. **9C**, when the position of the work vehicle **100** is shifted leftward from the target path **P**, the controller **180** changes the steering angle so that the traveling direction of the work vehicle **100** will be inclined rightward, thus bringing the work vehicle **100** closer to the path **P.** In this case, too, not only the steering angle but also the speed may be changed. The amount of change of the steering angle may be adjusted in accordance with the magnitude of the positional deviation Δx, for example.

[0099] As shown in FIG. **9D**, in the case where the position of the work vehicle **100** is not considerably deviated from the target path **P** but its orientation is nonetheless different from the direction of the target path **P**, the controller **180** changes the steering angle so that the directional deviation $\Delta\theta$ will become smaller. In this case, too, not only the steering angle but also the speed may be changed. The magnitude of the steering angle may be adjusted in accordance with the magnitudes of the positional deviation Δx and the directional deviation $\Delta\theta$, for example. For instance, the amount of change of the steering angle (which is in accordance with the directional deviation $\Delta\theta$) may be increased as the absolute value of the positional deviation Δx decreases. When the positional deviation Δx has a large absolute value, the steering angle will be changed greatly in order for the work vehicle **100** to return to the path **P**, so that the directional deviation $\Delta\theta$ will inevitably have a large absolute value. Conversely, when the positional deviation Δx has a small absolute value, the directional deviation $\Delta\theta$ needs to become closer to zero. Therefore, it may be advantageous to introduce a relatively large weight (i. e. , control gain) for the directional deviation $\Delta\theta$ in determining the steering angle.

[0100] For the steering control and speed control of the work vehicle **100**, control techniques such as PID control or MPC (Model Predictive Control) may be applied. Applying these control techniques will make for smoothness of the control of bringing the work vehicle **100** closer to the target path **P.**

[0101] Note that, when an obstacle is detected by one or more obstacle sensors **130** during travel, the controller **180** halts the work vehicle **100.** At this point, the controller **180** may cause the buzzer **220** to present an alarm sound or may transmit an alert signal to the terminal device **400.** In the case where the obstacle is avoidable, the controller **180** may control the drive device **240** such that the obstacle is avoided.

[0102] The work vehicle **100** according to the present embodiment can perform self-traveling outside a field as well as inside the field. Outside the field, the controller **180** is able to detect an object located at a relatively distant position from the work vehicle **100** (e.g. , another vehicle, a pedestrian, etc.) based on data output from the cameras **120** or the LiDAR sensor **140.** The controller **180** generates a local path such that the local path avoids the detected object, and performs speed control and steering control along the local path. In this manner, self-traveling on a road outside the field can be realized.

[0103] As described above, the work vehicle **100** according to the present embodiment can automatically travel inside the field and outside the field in an unmanned manner. FIG. **10** is a diagram schematically showing an example of state where a plurality of the work vehicles **100** are performing self-traveling inside a field **70** and on a road **76** outside the field **70.** In the storage device **170**, an environment map of a region including a plurality of fields and roads around the fields, and a target path, are recorded. The environment map and the target path may be generated by the management device **600** or the ECU **185.** In the case of traveling on a road, the work vehicle **100** travels along the target path while sensing the surroundings thereof by use of the sensing devices such as the cameras **120** and the LiDAR sensor **140**, with the implement **300** being raised. During travel, the controller **180** consecutively generates a local path and causes the work vehicle **100** to travel along the local path. This allows the work vehicle **100** to perform self-traveling while avoiding obstacles. During travel, the target path may be changed in accordance with the state.

[2-2. Creation of a work plan]

[0104] The work vehicle **100** according to the present embodiment automatically moves between the fields and performs agricultural work in each of the fields in accordance with a work plan and a target path created by the management device **600.** The work plan includes information on one or more tasks of agricultural work to be performed by the work vehicle **100.** For example, the work plan includes information on one or more tasks of agricultural work to be performed by the work vehicle **100** and on the field where each task is to be performed. The work plan may include information on a plurality of tasks of agricultural work to be performed by the work vehicle **100** over a plurality of working days and on the field where each task of agricultural work is to be performed. More specifically, the work plan may be a database including information on a work schedule indicating which agricultural machine is to perform which task of agricultural work in which field at which point of time for each working day. Hereinafter, an example case where the work plan is data of such a work schedule will be described. The work plan may be created by the processor **660** of the management device **600** based on information input by the user to the terminal device **400.** Hereinafter, an example of method for creating the work schedule will be described.

[0105] FIG. **11** is a diagram showing an example of setting screen **760** displayed on the display device **430** of the terminal device **400.** In response to a manipulation performed by the user by use of the input device **420**, the processor **460** of the terminal device **400** activates application software for schedule creation to cause the display device **430** to display the setting screen **760** as shown in FIG. **11.** The user can input information necessary to create a work schedule on the setting screen **760.**

[0106] FIG. **11** shows an example of the setting screen **760** in the case where tilling accompanied by spraying of a fertilizer is to be performed as the agricultural work in a field for rice farming. The setting screen **760** is not limited to the one shown in the figure, and may be changed when necessary. The setting screen **760** in the example of FIG. **11** includes a date setter **762**, a planting plan selector **763**, a field selector **764**, a work selector **765**, a worker selector **766**, a time setter **767**, a machine selector **768**, a fertilizer selector **769**, and a spray amount setter **770.**

[0107] The date setter **762** displays a date input by the input device **420.** The input date is set as the day when the agricultural work is to be performed.

[0108] The planting plan selector **763** displays a list of names of planting plans created previously. The user can select a desired planting plan from the list. The planting plan is created previously for each of types or each of breeds of the crop, and is recorded in the storage device **650** of the management device **600.** The planting plan is a plan regarding which crop is to be planted (seeded) in which field. The planting plan is created by, for example, a manager managing a plurality of fields before the crop is planted in one of the fields. In the example of FIG. **11**, a planting plan for rice breed "KOSHIIBUKI" is selected. In this case, the contents set by the setting screen **760** are associated with the planting plan of "KOSHIIBUKI".

[0109] The field selector **764** displays the fields in the map. The user can select any field from the fields displayed. In the example of FIG. **11**, an area indicating "field A" is selected. In this case, the selected "field A" is set as the field where the agricultural work is to be performed.

[0110] The work selector **765** displays a plurality of types of agricultural work necessary to grow the selected crop.

The user can select one type of agricultural work from the plurality of types of agricultural work. In the example of FIG. **11**, "tilling" is selected from the plurality of types of agricultural work. In this case, the selected "tilling" is set as the agricultural work to be performed.

[0111] The worker selector **766** displays workers registered previously. The user can select one or more workers from the plurality of workers displayed. In the example of FIG. **11**, "worker B" and "worker C" are selected from the plurality of workers. In this case the "worker B" and the "worker C" selected are set as the workers in charge of performing or managing the agricultural work. In the present embodiment, the agricultural machine performs agricultural work automatically. Therefore, the workers do not need to actually perform the agricultural work, and may merely remotely monitor the agricultural work performed by the agricultural machine.

[0112] The time setter **767** displays a work time period input by the input device **420.** The work time period is specified by a point of time to begin the agricultural work and a point of time to end the agricultural work. The input work time period is set as the time period in which the agricultural work is scheduled to be performed.

[0113] The machine selector **768** is used to set the agricultural machine to be used for the agricultural work. The machine selector **768** may display, for example, the types or models of the agricultural machines previously registered by the management device **600** and the types, models, etc. of usable implements. The user can select a specific machine from the machines displayed. In the example of FIG. **11**, the implement of model "NW4511" is selected. In this case, this implement is set as the machine to be used for the agricultural work.

[0114] The fertilizer selector **769** displays names of a plurality of fertilizers registered by the management device **600** previously. The user can select a specific fertilizer from the plurality of fertilizers displayed. The selected fertilizer is set as the fertilizer to be used for the agricultural work.

[0115] The spray amount setter **770** displays a numerical value input by the input device **420.** The input numerical value is set as the spray amount.

[0116] When the planting plan, the field, the agricultural work, the worker, the work time period, the fertilizer and the spray amount are input to the setting screen **760** and "register" is selected, the communication device **490** of the terminal device **400** transmits the input information to the management device **600.** The processor **660** of the management device **600** causes the storage device **650** to store the received information. Based on the received information, the processor **660** creates a schedule of the agricultural work to be performed by each agricultural machine and causes the storage device **650** to store the schedule.

[0117] Note that the information on the agricultural work to be managed by the managing device **600** is not limited to the above-described information. For example, the type and the spray amount of the agricultural chemical to be used in the field may be set by the setting screen **760.** Information on agricultural work other than the types of agricultural work shown in FIG. **11** may be set by the setting screen **760.**

[0118] FIG. **12** is a table showing an example of schedule (i.e. , work plan) of agricultural work created by the management device **600.** The schedule in this example includes information representing the date and time of the agricultural work, the field for the agricultural work, the contents of the work, and the implement to be used, for each of the registered agricultural machines. The schedule may include, in addition to the information shown in FIG. **12**, other information in accordance with the contents of work, for example, information on the types of agricultural chemicals or the spray amounts of the agricultural chemicals. The processor **660** of the management device **600** instructs the work vehicle **100** to perform the agricultural work in accordance with such a schedule. The schedule may be downloaded by the controller **180** of the work vehicle **100** and may also stored in the storage device **170.** In this case, the controller **180** may spontaneously begin the operation in accordance with the schedule stored in the storage device **170.**

[0119] In the present embodiment, the work plan is created by the management device **600.** The work plan may be created by another device. For example, the processor **460** of the terminal device **400** or the controller **180** of the work vehicle **100** may have a function of creating or updating the work plan.

[2-3. Global path planning]

[0120] Now, an operation of path planning according to the present embodiment will be described in more detail.

[0121] The management device **600** and the control system **160** of the work vehicle **100** according to the present embodiment cooperate with each other to function as a path planning system for the work vehicle **100.** The storage device **650** stores a map including a plurality of fields and roads around the fields. The map includes attribute information representing, for each of the roads, at least one of whether the road is an agricultural road, whether the road is a road along a specific feature such as a waterway, or whether the road is a road where satellite signals from GNSS satellites can be properly received. The processor **660** of the management device **600** functions as a processing unit that generates a path for the work vehicle **100** on the map. The processor **660** may be configured to generate a path for the work vehicle **100** outside the fields in accordance with the schedule of the agricultural work previously created. For generation of a path toward a field or a path from a field toward another site, the processor **660** generates at least one of a path including an agricultural road with priority, a path including a road along a specific feature with priority, or a path including, with priority, a road where satellite signals can be properly received. The processing unit generates at least one of these paths as the path for the work vehicle **100** based on the attribute information on each road. As a result, a path suitable to self -traveling of the work vehicle **100** can be generated. Note that a portion of, or the entirety of, a path generation process, which is to be performed by the management device **600**, may be performed by the ECU **185** of the controller **180** of the work vehicle **100.** In this case, a combination of the ECU **185** and the management device **600** functions as a processing unit that generates a path for the work vehicle **100.** Alternatively, a portion of, or the entirety of, the path generation process, which is to be performed by the management device **600**, may be performed by the operational terminal **200** of the work vehicle **100.** In this case, a combination of the operational terminal **200** and the management device **600** functions as a processing unit that generates a path for the work vehicle **100.**

[0122] It is preferred that the work vehicle **100** performing self-traveling travels on an agricultural road where the amount of traffic is small with priority over a general road where many general vehicles and many people come and go. For performing self-traveling outside the fields, the work vehicle **100** may be configured to travel while performing localization based on the data output from at least either one of the LiDAR sensor **140** or the cameras **120.** In this case, it is preferred that the work vehicle **100** travels, with priority, on a road along a specific feature (e.g., a waterway, a river, a row of trees, a building or the like) which may be a landmark for the localization. In addition, in the case where the work vehicle **100** also uses the data output from the GNSS unit **110** for the localization, it is preferred that the work vehicle **100** travels, with priority, on a road where satellite signals from GNSS satellites can be properly received.

[0123] For the above-described reason, in the present embodiment, the management device **600** generates at least one of a path including an agricultural road with priority, a path including a road along a specific feature with priority, or a path including, with priority, a road where satellite signals can be properly received. The management device **600** generates at least one of these paths as the path for the work vehicle **100** based on the attribute information on each of the roads on the map. As a result, a path more suitable to self - traveling can be generated than in the case where merely a path providing a minimum moving distance or moving time is selected.

[0124] The management device **400** may have a function of generating all of a path including an agricultural road with priority, a path including a road along a specific feature with priority, and a path including, with priority, a road where satellite signals can be properly received, or may generate only one or two among these paths. Alternatively, the management device **600** may be configured to generate a path including, with priority, all of an agricultural road, a road along a specific feature and a road where satellite signals can be properly received. The management device **600** may determine one path selected based on a predetermined criterion from a plurality of generated paths, as the path for the work vehicle **100.** For example, the management device **600** may cause the display device **430** of the terminal device **400** to display the plurality of the generated paths and determine a path selected from these paths by the user as the path for the work vehicle **100.**

[0125] The management device **600** may generate a path in a mode selected by the user from a plurality of modes including at least one of a first mode to select an agricultural road with priority to generate a path, a second mode to select a road along a specific feature with priority to generate a path, or a third path to select a road where satellite signals can be properly received to generate a path. The plurality of modes may further include a fourth mode to generate a path such that the moving time or the moving distance of the work vehicle **100** is shortest. The management device **600** may cause the display device **430** of the terminal device **400** to display a graphical user interface (GUI) to allow the user to select one mode from the plurality of modes, and generate a path in the selected mode.

[0126] FIG. **13** is a diagram showing an example of GUI displayed on the display device **430.** The GUI in this example allows the user to select one of three modes of "agricultural road prioritized", "waterway prioritized" and "GNSS prioritized". In the example shown in FIG. **13**, "agricultural road prioritized" corresponds to the first mode, "waterway prioritized" corresponds to the second mode, and "GNSS prioritized" corresponds to the third mode. FIG. **13** shows a state where "agricultural road prioritized" is selected as an example.

[0127] The management device **600** automatically generates a path from a departure point to a target point of self-traveling of the work vehicle **100.** The departure point and the target point may be set by the user previously, or may be set by the management device **600** in accordance with a work plan created previously. The management device **600** generates a path from the departure point to the target point at a predetermined timing after the departure point and the target point are set but before the self-traveling begins.

[0128] In the case where "agricultural road prioritized" is selected on the GUI shown in FIG. **13**, the management device **600** selects an agricultural road with priority to generate a path. By contrast, in the case where "waterway prioritized" is selected, the management device **600** selects a road along a waterway with priority to generate a path. The waterway is an example of specific feature that functions as a landmark for localization performed by use of the LiDAR sensor **140** or the cameras **120.** A mode to generate a path with priority being put on a road along another type of feature, in addition to the waterway or instead of the waterway, may be provided. In the case where "GNSS prioritized" is selected, the management device **600** generates a path with propriety being put on a road where satellite signals from GNSS satellites can be properly received.

[0129] Hereinafter, an example of path generation process performed by the management device **600** will be described with reference to FIG. **14.** It is assumed that the departure point and the target point of self-traveling of the work vehicle **100** are already set.

[0130] FIG. **14** is a flowchart showing a path generation process performed by the management device **600** in the example shown in FIG. **13.** In this example, first, in step **S201**, the management device **600** determines whether either one of the modes has been selected by the user. When the user selects either one of "agricultural road prioritized", "waterway prioritized" or "GNSS prioritized" shown in FIG. **13** and presses "determine", the process advances to step **S202.** In step **S202**, the management device **600** identifies the selected mode. In the case where "agricultural road prioritized" is selected, the process advances to step **S203.** In the case where "waterway prioritized" is selected, the process advances to step **S204.** In the case where "GNSS prioritized" is selected, the process advances to step **S205** . In step **S203**, the management device **600** generates a path including an agricultural road with priority, as the path for the work vehicle **100.** In step **S204**, the management device **600** generates a path including a road along a waterway with priority, as the path for the work vehicle **100.** In step **S205**, the management device **600** generates a path including, with priority, a road where satellite signals can be properly received, as the path for the work vehicle **100.** Specific examples of the processes of steps **S203, S204** and **S205** will be described below. Upon generation of the path, the management device **600** advances to step **S205** to cause the storage device **650** to store the generated path. In step **S206**, the management device **600** transmits the generated path to the work vehicle **100** at a predetermined timing. The work vehicle **100** performs self - traveling in accordance with the generated path and the work schedule previously acquired.

[0131] In the example shown in FIG. **13** and FIG. **14**, the management device **600** generates a path in one mode selected by the user from the three modes of "agricultural road prioritized" , "waterway prioritized" and "GNSS prioritized". Alternatively, the system may be configured to allow the user to select a mode for a desired priority item from a larger number of modes.

[0132] FIG. **15** is a diagram showing another example of GUI displayed on the display device **430.** In this example, the modes of "time prioritized" and "manual settings" are added to "agricultural road prioritized", "waterway prioritized" and "GNSS prioritized" . The user can select one mode from these five modes. In this example, "agricultural road prioritized" corresponds to the first mode, "waterway prioritized" corresponds to the second mode, "GNSS prioritized" corresponds to the third mode, and "time prioritized" corresponds to a fourth mode. "Manual settings" is a mode in which the user sets a path manually while looking at the map displayed.

[0133] The path generation process in the case where "agricultural road prioritized", "waterway prioritized" or "GNSS prioritized" is selected is as described above. In the case where "time prioritized" is selected, the management device **600** generates a path connecting the departure point and the target point to each other such that the moving time of the work vehicle **100** is shortest. In the case where "manual settings" is selected, the management device **600** causes the display device **430** to display a map of a region where the work vehicle **100** is to travel, and allows the user to select a path. Hereinafter, a specific example of the operation in each of the modes will be described.

[0134] FIG. **16** is a diagram showing an example of map of the region where the work vehicle **100** is to travel. Such a map may be displayed on the display device **430.** This map is a two-dimensional digital map, and is generated by the management device **600** or another device. The map as shown in FIG. **16** may be created for the entirety of the region where the work vehicle **100** may travel. Note that the map shown in FIG. **16** is a two-dimensional map, but a three-dimensional map may be used for the path planning.

[0135] The map shown in FIG. **16** includes information on a position (e.g. , the latitude and the longitude) of each of various points in a plurality of fields **70** where the work vehicle **100** is to perform agricultural work, in roads **76** around the fields **70**, and in a feature such as a waterway **78** or the like. The map further includes attribute information representing, for each of the roads, at least one of whether the road **76** is an agricultural road, whether the road **76** is a road along a specific feature such as the waterway **78**, or whether the road **76** is a road where satellite signals from GNSS satellites can be properly received. In addition to such attribute information, attribute information representing the width of each road **76** at each of various points may be included in the map. Based on the width of each road **76** at each point, the management device **600** can determine whether the work vehicle **100** can pass along the road **76.** The map may include attribute information representing whether the road **76** is a general road instead of the agricultural road. Based on such attribute information, the management device **600** can generate a path along which a general road is avoided.

[0136] The map shown in FIG. **16** shows a departure point **S** and a target point **G** of self-traveling of the work vehicle **100** with star marks **"★".** The departure point **S** and the target point **G** may be set by, for example, the user. Alternatively, the management device **600** may set the departure point **S** and the target point **G** in accordance the work schedule on each of working days. The work schedule on each working day is previously generated by the management device **600** as described above with reference to FIG. **12**, and stored in the storage device **650.** In addition to the departure point **S** and the target point **G**, one or more waypoints may be set. For the departure point **S**, for the target point **G** and for each of the waypoints, both of, or one of, the time when the work vehicle **100** is scheduled to arrive and the time when work vehicle **100** is scheduled to depart may be recorded.

[0137] In the case "manual settings" is selected, the user can designate a desired path by, for example, a manipulation of designating a plurality of waypoints on, for example, a intersection on the displayed map. In the case where a mode other than "manual settings" is selected, the management device **600** automatically generates a path reaching the target point **G** from the departure point **S** by a predetermined algorithm corresponding to the selected mode.

[0138] FIG. **17** is a diagram showing an example of path generated in the case where the "agricultural road prioritized" mode is selected. In this mode, the management device **600** determines, as the path for the work vehicle **100**, a path **75A** having a relatively high ratio of agricultural roads and providing a relatively short moving distance or moving time, among a plurality of paths reaching the target point **G** from the departure point **S.** For example, the management device **600** may determine, as the path for the work vehicle **100**, a path of which the ratio of the agricultural roads with respect to the entirety of the path is higher than a predetermined value (e.g., 80%, 90% or the like) and by which the moving distance or moving time is shortest. In the "agricultural road prioritized" mode, in the case where, as in the example of FIG. **16,** a plurality of path candidates reaching the target point **G** from the departure point **S** include a path candidate passing along an agricultural road **76g** and a path candidate passing along a general road **76f,** the management device **600** selects the path candidate passing along the agricultural road **76g** with priority over the path candidate passing along the general road **76f.** Alternatively, the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the agricultural roads with respect to the entirety of the path is higher than a predetermined value and which matches the schedule of the agricultural work on that working day. For example, the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the agricultural roads with respect to the entirety of the path is higher than a predetermined value and by which a final task of agricultural work on that working day is completed before the time when the agricultural work is to end, in accordance with the schedule. Alternatively, in the case where the work vehicle **100** is to perform the agricultural work in a plurality of fields after departing from the departure point **S** before reaching the target point **G,** the management device **600** may generate, based on the schedule, a path of which the ratio of the agricultural roads is higher than a predetermined value and by which the work vehicle **100** can arrive at each of the fields before the time when the respective task of agricultural work is to begin. In addition to the condition that the ratio of the agricultural roads is higher than a predetermined value, a condition that the ratio of the general roads is no higher than a reference value may be provided.

[0139] FIG. **18** is a diagram showing an example of path generated in the case where the "waterway prioritized" mode is selected. In this mode, the management device **600** determines, as the path for the work vehicle **100,** a path **75B** having a relatively high ratio of roads along the waterway **78** and providing a relatively short moving distance or moving time, among a plurality of paths reaching the target point **G** from the departure point **S.** The waterway **78** may function as a landmark for localization performed by use of the LiDAR sensor **140** or the cameras **120.** The road along the waterway **78** is prioritized, so that a path by which the error for the localization is small can be generated. Note that a feature other than the waterway **78** (e.g., a river, a row of trees, grass, a building or the like) may be used as a landmark for the localization. In this case, the management device **600** may determine a path with priority being put on roads along one or more types of features that may function as landmarks. The landmark is not limited to the waterway **78.** In this mode, for example, the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the roads along a specific feature with respect to the entirety of the path is higher than a predetermined value (e.g., 300, 500 or the like) and by which the moving distance or moving time is shortest. Alternatively, the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the roads along a specific feature with respect to the entirety of the path is higher than a predetermined value and which matches the schedule of the agricultural work on that working day. For example, the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the roads along a specific feature is higher than a predetermined value and by which a final task of agricultural work on that working day is completed before the time when the agricultural work is to end, in accordance with the schedule. Alternatively, in the case where the work vehicle **100** is to perform the agricultural work in a plurality of fields after departing from the departure point **S** before reaching the target point **G,** the management device **600** may generate, as the path for the work vehicle **100,** a path of which the ratio of the roads along a specific feature is higher than a predetermined value and by which the work vehicle **100** can arrive at each of the fields before the time when the respective task of agricultural work is to begin, based on the schedule.

[0140] FIG. **19** is a diagram showing another example of map of a region where the work vehicle **100** is to travel. The map shown in FIG. **19** includes a forest or mountain including a plurality of trees **77** and a river **79** in addition to the plurality of fields **70** and the roads **76** around the fields **70.** In this example, the departure point **S** and the target point **G** are set on a road adjacent to rows of the trees **77.**

[0141] FIG. **20** is a diagram showing an example of path generated in the case where the "GNSS prioritized" mode is selected in the example shown in FIG. **19.** In this mode, the management device **600** selects, with priority, a path **75C** having a relatively high ratio of roads where satellite signals from GNSS satellites can be properly received, from a plurality of paths reaching the target point **G** from the departure point **S.** In the example shown in FIG. **20,** on a path by which the work vehicle **100** can reach the target point **G** from the departure point **S** within the shortest time, radio waves from the GNSS satellites are partially blocked by the rows of trees growing thick in the vicinity of the work vehicle **100,** the mountain and the like. This easily causes a reception failure of the satellite signals. Therefore, instead of such a path, the path **75C,** where the reception strength of the satellite signals is stably high, is determined as the path for the work vehicle **100.** Note that in the example shown in FIG. **20,** it is assumed that the work vehicle **100** is not allowed to pass along a road on either side of the river **79.** Therefore, the path **75C,** which causes the work vehicle **100** to travel from the departure point **S** toward the target point **G** while crossing the river **79** and thus is relatively long, is generated. In the case where the work vehicle **100** is allowed to pass along the roads along the river **79,** the management device **600** may generate a path to reach the target path **G** via these roads. Alternatively, the management device **600** may generate a path including, with priority, both of a road where satellite signals can be properly received and a road along a specific feature such as the river **79** or the waterway.

[0142] In the example shown in FIG. **20,** the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the roads where satellite signals can be properly received is high and by which the moving distance is relatively short, among a plurality of paths reaching the target point **G** from the departure point **S.** For example, the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the roads where satellite signals can be properly received, with respect to the entirety of the path, is higher than a predetermined value (e.g. , 80%, 90% or the like) and by which the moving time is shortest. In the "GNSS prioritized" mode, for generation of a path reaching the target point **G** from the departure point **S**, the management device **600** generates a path with priority being put on a road extending to be away from the rows of trees, the mountain or the like by a predetermined distance or longer or a road located away from the rows of trees, the mountain or the like by the predetermined distance or longer, over another road located away from the rows of trees, the mountain or the like by a distance shorter than the predetermined distance. In the case of, for example, FIG. **20,** from a plurality of roads **76a, 76b, 76c** and **76d**, the management device **600** selects, with priority, the roads **76b** and **76d** extending to be away from the rows of trees, the mountain or the like by the predetermined distance or longer and the road **76c** located away from the rows of trees, the mountain or the like by the predetermined distance or longer. The management device **600** generates a path continuous along these roads, and also generate a path along a portion of the road **76a** connected to the target point **G.** Alternatively, the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the roads where satellite signals can be properly received, with respect to the entirety of the path, is higher than a predetermined value and which matches the schedule of the agricultural work on that working day. For example, the management device **600** may determine, as the path for the work vehicle **100,** a path of which the ratio of the roads where satellite signals can be properly received is higher than a predetermined value and by which a final task of agricultural work on that working day is completed before the time when the agricultural work is to end, in accordance with the schedule. Alternatively, in the case where the work vehicle **100** is to perform agricultural work in a plurality of fields after departing from the departure point **S** before reaching the target point **G,** the management device **600** may generate, as the path for the work vehicle **100,** a path of which the ratio of the roads where satellite signals can be properly received is higher than a predetermined value and by which the work vehicle **100** can arrive at each of the fields before the time when the respective task of agricultural work is to begin, based on the schedule.

[0143] FIG. **21** is a diagram schematically showing an example of state where the work vehicle **100** is traveling in the vicinity of a row of trees. In this example, a plurality of trees **77** grow in the vicinity of the path along which the work vehicle **100** is traveling. A portion of branches of the trees **77** covers the work vehicle **100** and blocks reception of the satellite signals. In such an environment, many of the signals transmitted from the satellites **50** are blocked by the branches of the trees **77.** As a result, the reception strength of the satellite signals is significantly decreased, and the reliability of positioning is lowered. In the "GNSS prioritized" mode, a path for the work vehicle **100** is determined so as to avoid such a road to a maximum possible degree. As a result, the reduction in the reliability of the positioning performed based on the GNSS data can be avoided, and the self-traveling can be stabilized.

[0144] In the case where the "GNSS prioritized" mode is selected, the management device **600** determines whether the road is a road where satellite signals can be properly received, based on the attribute information on each road included in the map. The attribute information may be generated based on the GNSS data output from the GNSS receiver mounted on the work vehicle **100** or another movable body. The another movable body may be a movable body of a different type from that of the work vehicle **100** such as an automobile or a drone (i.e., an unmanned aerial vehicle (UAV)). The work vehicle **100** or the another movable body collect the GNSS data while moving along the road along which the work vehicle **100** is to perform self-traveling. The GNSS data is collected a plurality of times at different times of the year for each road. A reason for this is that the positional arrangement of the plurality of GNSS satellites is different at different times of the year. The degree by which the branches and leaves of the trees block the reception of the satellite signals may be different season by season, and therefore, the GNSS data on each road may be collected in a plurality of different seasons. Based on the GNSS data collected a plurality of times for each road, attribute information representing whether the road is a road where the satellite signals can be properly received may be generated. The attribute information may be generated by, for example, the management device **600.**

[0145] FIGS. **22A** and **22B** each show an example of reception strength of the satellite signals. FIG. **22A** shows an example of reception strength of each satellite signal on a road where the satellite signals can be properly received. FIG. **22B** shows an example of reception strength of each satellite signal on a road where the satellite signals cannot be received in a normal state (i.e., where a reception failure may occur). In these examples, satellite signals from 12 satellites are received, and the reception strength is expressed by the value of the carrier to noise density ratio (C/NO) . Note that this is merely an example, and the number of the satellites from which the satellite signals may be received, and how the reception strength is expressed, depend on the system. In one example, presence/absence of a reception failure can be determined based on whether the number of satellites, the satellite signals from which are received at a reception strength exceeding a preset reference value, is no lower than a threshold value (e.g., 4). In FIGS. **22A** and **22B**, an example of reference value for the reception strength is shown by the broken line. In the case where the threshold value is, for example, four, in the example shown in FIG. **22A,** the reception strength of the satellite signals from five satellites exceed the reference value, which is not lower than the threshold value. In this case, it may be determined that the reception failure is not occurring. By contrast, in the example shown in FIG. **22B,** the reception strength of the satellite signals from one satellite exceeds the reference value, which is lower than the threshold value. In this case, it may be determined that the reception failure is occurring. A road where it is determined that, for example, the reception failure is not occurring in any time of the year based on the GNSS data collected at a plurality of different times of the year for each road can be determined as a "road where satellite signals can be properly received". Note that ease of reception of the satellite signals may be different in different sites of the same road. Therefore, attribute information representing whether satellite signals can be properly received may be recorded for each pair of coordinate values (e.g., the latitude and the longitude) on the road. The above-described method is merely an example, and another method may be used to determine whether satellite signals can be properly received regarding each road. For example, in the case where the GNSS data includes a value representing the reliability of positioning, it may be determined, based on the value of the reliability, whether satellite signals can be properly received.

[0146] FIG. **23** is a diagram showing an example of path generated by the management device **600** in the case where the "time prioritized" mode is selected. In this example, the management device **600** generates, as the path for the work vehicle **100,** a path **75D,** by which the work vehicle **100** can reach the target point **G** from the departure point **S** within the shortest time. The path **75D** is generated on a road along the row of the trees **77.** Such a path is effective in the case where, for example, the work vehicle **100** performs localization based on the data acquired by the LiDAR sensor **140** or the cameras **120** with no use of the GNSS data. In the case where the localization is performed based on the data acquired by the LiDAR sensor **140** or the cameras **120,** the management device **600** may determine, as the path for the work vehicle **100,** a path including a road where satellite signals cannot be received in a normal state.

[0147] In the above-described examples, the management device **600** performs global path planning for the work vehicle **100** in a mode selected by the user from the plurality of modes. As a result, a path reflecting the user's intention can be generated. In the above-described examples, five modes of "agricultural road prioritized", "waterway prioritized", "GNSS prioritized", "time prioritized" and "manual settings" are provided as examples. These are merely examples . The management device **600** may generate a path in, for example, at least one mode among "agricultural road prioritized", "waterway prioritized", "GNSS prioritized", "time prioritized" and "manual settings". Instead of a function of allowing the user to select the mode being provided, the management device **600** may generate a path including, with priority, at least one of an agricultural road, a road along a specific feature such as a waterway, or a road where satellite signals can be properly received, as the path for the work vehicle **100** in accordance with a predetermined algorithm.

[0148] For example, the management device **600** may calculate an evaluation value for each of a plurality of paths reaching the target point from the departure point of the work vehicle **100** based on the attribute information on each of roads along which the work vehicle **100** is to pass and on a predetermined evaluation function, and determine one path selected based on the evaluation value as the path for the work vehicle **100.** Specifically, an evaluation function as follows is used. Among a plurality of paths reaching the target point from the departure point, a path of which the ratio of the agricultural roads, the ratio of the roads along a specific feature, or the ratio of the roads where satellite signals can be properly received is higher is given a smaller evaluation value, whereas a path by which the moving distance or moving time is longer is given a larger evaluation value. The management device **600** may determine a path by which such an evaluation function is minimum, as the path for the work vehicle **100.** For example, it is assumed that the ratio of the length of the agricultural roads with respect to the entirety of the path is r_1, the ratio of the length of the roads along a specific feature with respect to the entirety of the path is r_2, the ratio of the length of the roads where satellite signals can be properly received, with respect to the entirety of the path, is r_3, and the total length of the path is d. The evaluation function may be expressed by, for example, the following function f:

[Expression 1]

$$f(r_1, r_2, r_3, d) = \frac{k_3 d}{k_1 r_1 + k_2 r_2 + k_3 r_3}$$

In the above expression , k_1, k_2, k_3 and k_4 are each a coefficient of 0 or greater, and respectively represent weights for

r_1, r_2, r_3 and r_4. Coefficients k_1, k_2, k_3 and k_4 are appropriately set, so that the evaluation value can be made smaller as the ratio r_1 of the agricultural roads, the ratio r_2 of the roads along a specific feature, or the ratio r_3 of the roads where satellite signals can be properly received is higher, whereas the evaluation value can be made larger as the total length d of the path is longer. One or two among k_1, k_2 and k_3 may be zero (0) . For example, in the case where $k_2 = 0$ and $k_3 = 0$, the management device **600** generates a path with only the agricultural roads being prioritized. The management device **600** may change the type of roads to be prioritized by adjusting the values of coefficients k_1, k_2, k_3 and k_4 in accordance with the mode selected by the user. Note that the evaluation function f is not limited to the above function, and any other evaluation function may be used.

[0149] Oppositely to the above-described example, among a plurality of paths reaching the target point from the departure point, a path of which the ratio of the agricultural roads, the ratio of the roads along a specific feature, or the ratio of the roads where satellite signals can be properly received is higher may be given a larger evaluation value, whereas a path by which the moving distance or moving time is longer may be given a smaller evaluation value. The management device **600** may determine a path by which such an evaluation function is maximum, as the path for the work vehicle **100.**

[0150] Now, a specific example of path planning method based on a work plan will be described.

[0151] Before the agricultural work begins on each of working days, the management device **600** reads, from the storage device **650,** a map of a region including the field(s) where the agricultural work is to be scheduled on that working day, and generates a path for the work vehicle **100** based on the map. More specifically, the management device **600** generates a first path, along which the work vehicle **100** is to travel while performing the agricultural work inside a field **70** (the first path is also referred to as a "tasked travel path"), on the field on the map, and generates a second path, along which the work vehicle **100** is to travel toward the field **70,** on a road on the map. After generating the first path and the second path, the management device **600** connects the first path and the second path to each other to generate a global path for the work vehicle **100.** As described above, the second path may be generated such that at least one of an agricultural road, a road along a specific feature, or a road where satellite signals can be properly received is prioritized.

[0152] FIG. **24** is a diagram showing an example of global path to be generated. FIG. **24** shows, as an example, a field group **70A,** where the agricultural work is to be performed on one working day, a field group **70B,** where the agricultural work is to be performed on the next day, and a field group **70C,** where the agricultural work is to be performed on the day after the next day. FIG. **24** also shows, as an example, a repository **90** for the work vehicle **100,** a house **92** of the user performing remote monitoring of the work vehicle **100,** and two waiting areas **96A** and **96B,** where the work vehicle **100** is to wait. In FIG. **14,** the field group **70A,** the field group **70B,** the field group **70C,** the repository **90,** the waiting area **96A** and the waiting area **96B** are shown as being relatively close to each other for the sake of convenience. In actuality, the distances between the field group **70A,** the field group **70B,** the field group **70C,** the repository **90,** the waiting area **96A** and the waiting area **96B** may be long, for example, 500 m to 1 km or even longer.

[0153] A repository may be, for example, a garage, a barn or a parking area adjacent to a house or an office of the user. A waiting area may be, for example, a site that is managed or used jointly by a plurality of users. The waiting area may be a facility such as a parking area or a garage managed or run by a regional government of a city, a town or a village, an agricultural cooperative or a corporation. In the case where the waiting area is a facility locked at nighttime, the work vehicle **100** in the waiting area can be prevented from being robbed. FIG. **24** shows two waiting areas **96A** and **96B** as examples, but any number of waiting areas may be provided. In the case where the work vehicle **100** moves around within a relatively small range, there is no need to provide the waiting area **96** separately from the repository **90.** The repository **90** and the waiting area **96** may be registered by a manipulation performed by the user by use of the terminal device **400.**

[0154] In FIG. **24,** paths, of the paths generated by the management device **600,** which are generated on the roads **76** are represented by arrows. The tasked travel paths generated inside the fields are omitted. Solid line arrows represent an example of paths for the work vehicle **100** on one working day, and broken line arrows represent an example of paths for the work vehicle **100** on the next working day.

[0155] In the example shown in FIG. **24,** the management device **600** generates, as a path for one working day, a path along which the work vehicle **100** departs from the repository **90,** sequentially passes the fields in the field group **70A** and reaches the waiting area **96A.** This is because the waiting area **96A** is the waiting area closest to the field group **70B,** where the agricultural work is scheduled to be performed on the next working day. The management device **600** generates, as a path for the next working day, a path along which the work vehicle **100** departs from the waiting area **96A,** sequentially passes the fields in the field group **70B** and reaches the waiting area **96B.** This is because the waiting area **96B** is the waiting area closest to the field group **70C,** where the agricultural work is scheduled to be performed on the day after the next working day. In this manner, the management device **600** generates a path from the field where the final task of agricultural work is to be performed on each working day, to the waiting area located at the shortest average distance from the group of fields where the agricultural work is to be performed on the next working day. As described above, the management device **600** can generate a path with priority being put on an agricultural road, a road along a specific feature, or a road where satellite signals can be properly received, in accordance with the selection of the user. The work vehicle **100** travels along the generated path.

[0156] In the example shown in FIG. **24,** on one working day, the work vehicle **100** departs from the repository **90,** and sequentially visits the fields in the field group **70A,** where the agricultural work is scheduled to be performed on the day, and performs the agricultural work indicated by the schedule in each field. In each field, the work vehicle **100** performs the agricultural work while performing self-traveling along the tasked travel path by, for example, the method described above with reference to FIG. **7** to FIG. **9D.** When the agricultural work ends in one field, the work vehicle **100** enters the next field, and performs the agricultural work in substantially the same manner. The work vehicle **100** operates in this manner, and when the agricultural work ends in the field assigned to the final task of agricultural work for the day, the work vehicle **100** moves to the waiting area **96A.** The work vehicle **100** waits at the waiting area **96A** until the next working day. On the next working day, the work vehicle **100** departs from the waiting area **96A** and sequentially visits the fields in the field group **70B,** where the agricultural work is scheduled to be performed on the day, and performs the agricultural work indicated by the schedule in each field. When the agricultural work ends in the field assigned to the final task of agricultural work for the day, the work vehicle **100** moves to the waiting area **96B.** The work vehicle **100** waits at the waiting area **96B** until the day after the next working day. On the day after the next working day, the work vehicle **100** departs from the waiting area **96B,** sequentially performs the agricultural work in the fields in the field group **70C,** and then moves to a predetermined waiting area in substantially the same manner. With such an operation, the work vehicle **100** is moved efficiently along an optimal path in accordance with the schedule, so that the scheduled agricultural work can be completed.

[0157] In the case where a plurality of waiting areas (including the repository **90**) are provided in the environment where the work vehicle **100** travels as in the present embodiment, data indicating the correspondence between the plurality of waiting areas and the plurality of fields (e.g. , a table) may be previously recorded in the storage device **650.** FIG. **25** is a table showing an example of the correspondence between the waiting areas and the fields . The correspondence between the waiting areas and the fields may be determined based on, for example, a moving distance from each of the waiting areas to each of the fields. In the example shown in FIG. **25**, the waiting area closest to the fields #1 to #30 is the waiting area A, the waiting area closest to the fields #31 to #60 is the waiting area B, and the waiting area closest to the fields #61 to #100 is the waiting area C. Referring to such a table, the management device **600** can determine the waiting area closest to the field where the agricultural work is scheduled to be performed on the next working day. One or more waiting areas **96** are provided in addition to the repository **90** as in this example, so that the time and the amount of consumption of the fuel required to move the work vehicle **100** can be decreased as compared with in the case where the work vehicle **100** returns to the repository **90** each day. As a result, a series of tasks of agricultural work over a plurality of working days can be performed more efficiently.

[0158] Now, with reference to FIG. **26**, an example of method for generating a global path will be described in more detail.

[0159] FIG. **26** is a diagram showing an example of global path generated on one working day. In this example, the management device **600** generates a path along which the work vehicle **100** departs from the waiting area **96**, passes four fields **70**, and returns to the waiting area **96.** The management device **600** generates a first path (tasked travel path) **30A** inside each of the fields **70,** and generates second paths **30B** on the roads **76** around the fields **70.** In FIG. **26**, the first path **30A** is shown only inside the left bottom field **70**, and the first paths inside the other fields **70** are omitted.

[0160] The management device **600** generates the first path **30A** as represented by the solid line arrows in FIG. **26**, inside each of the fields **70** on the map. The management device **600** generates the first path **30A** based on the settings previously made by the user as described above with reference to FIG. **7.** The first path **30A** may be generated so as to cover the entirety of the work area **72** by repeating a reciprocating motion from a beginning point **30S** to an ending point **30G.** The interval between rows of the first path **30A** may be determined in consideration of the width and the turning performance of each of the work vehicle **100** and the implement **300.**

[0161] The management device **600** further generates a path from the waiting area **96** to each of the fields **70** and paths connecting such a plurality of fields **70** as second paths **30B.** In the example shown in FIG. **26,** the management device **600** generates a second path **30B** at an entrance of each field **70** in addition to the second paths **30B** on the roads **76,** and generates a third path **30C** connecting the second path **30B** generated at each entrance and the beginning point **30S** of the corresponding first path **30A** to each other. The management device **600** further generates a second path **30B** at an exit of each field **70** in addition to the second paths **30B** on the roads **76,** and generates a fourth path **30D** connecting the second path **30B** generated at each exit and the ending point **30G** of the corresponding first path **30A** to each other. In the example shown in FIG. **26,** the entrance and the exit of each field **70** are common to each other, and will be expressed as an "entrance/exit **71"**, hereinafter. Each field **70** may have a plurality of entrances/exits **71,** or the entrance and the exit may be provided at different positions. The environment map includes positional information on the entrance/exit **71** (or the entrance and the exit) of each field **70** in addition to the positional information on each field **70.** The management device **600** can generate the second paths **30B** based on the positional information on the entrance/exit **71.**

[0162] The management device **600** according to the present embodiment generates the third path **30C** and the fourth path **30D** in a region other than a region, of the field **70,** where the agricultural work has been performed. In the example of FIG. **26,** it is assumed that a previous task of agricultural work has already been performed in the work area **72.** Therefore, the management device **600** generates the third path **30C** and the fourth path **30D** in the headland **74** while avoiding the work area **72.** This can prevent the work area **72,** where the agricultural work has already been performed, from being trampled by the work vehicle **100.** In the case where no agricultural work has been performed in the field **70** in this season (that is, in the case where the current task of agricultural work is the first task in this season), the third path **30C** may overlap the work area **72.** Meanwhile, the fourth path **30D** is a path that is set after the current task of agricultural work is completed, and therefore is set so as not to overlap the work area **72.**

[0163] In the word area **72,** a plurality of types of agricultural work are performed at different times. For example, agricultural work such as tilling, planting, manure spreading, preventive pest control, and harvesting may be performed at different times. In the case where a certain type of agricultural work has already been performed in the work area **72,** if the work vehicle **100** tramples the work area **72,** the effect of the agricultural work already performed is spoiled. Therefore, in the case where a certain type of agricultural work has already been performed in the work area **72,** the management device **600** according to the present embodiment avoids the work area **72** to generate the third path **30C** and the fourth path **30D.** In which region the agricultural work has already been performed can be determined based on the work plan. The management device **600** can generate the third path **30C** and the fourth path **30D** in a region other than the region where the agricultural work has already been performed, based on the work plan.

[0164] The management device **600** can perform the above-described path generation process for each of the fields **70** and each of the roads **76** around the fields **70** to generate all the paths for a predetermined time period (e.g., half a day, one day, three days, etc.) . For example, before the work vehicle **100** begins traveling on each working day, the management device **600** may generate all the paths necessary to complete all the tasks of agricultural work scheduled for that working day. Alternatively, the management device **600** may first generate a path necessary to perform a portion of the agricultural work scheduled for each working day, and then, after the portion of the agricultural work ends, may generate a path necessary to perform the remaining portion of the agricultural work for that working day. Still alternatively, the management device **600** may generate, all at once, all the paths necessary to complete all the tasks of agricultural work scheduled over a plurality of working days. The management device **600** may change the path, once generated, in accordance with various states such as the state of progress of the agricultural work, the state of weather, the traffic state, or the state of the agricultural road.

[0165] In the example shown in FIG. **26,** the work plan indicates that the agricultural work is performed in a plurality of fields **70** in a predetermined time period (e.g. , on one working day) . Therefore, the management device **600** generates a path from the waiting area **96** to one field **70** and a path between the fields **70,** along the roads **76.** A portion from such an example, there is a case where the work plan indicates that the agricultural work is performed in one field **70** in a predetermined time period. In this case, the management device **600** generates a path from the waiting area **96** to one field **70,** along the roads **76** leading to the field **70.** The management device **600** further generates a path from the field **70** where the final task of agricultural work is to be performed in the predetermined time period, as indicated by the work plan, to a return site to which the work vehicle **100** is to return, along the roads **76.** In the example shown in FIG. **26,** the waiting area **96** corresponds to the return site. The return site may be a site different from the waiting area **96** (e.g., the repository **90** shown in FIG. **24**).

[0166] As a result of the above-described operation, the management device **600** can generate a global path from the departure point of the work vehicle **100** to the target point via one or more fields **70** for every predetermined time period (e.g. , every working day). The management device **600** can generate a global path for the work vehicle **100** such that the work vehicle **100** performs the agricultural work in the specified field **70** at the specified point of time in accordance with the schedule previously created. Information on the generated global path is transmitted to the work vehicle **100** and stored in the storage device **170.** The ECU **184,** performing self-driving control, controls the ECUs **181** and **182** such that the work vehicle **100** travels along the global path. This allows the work vehicle **100** to begin traveling along the global path.

[2-4. Local path planning]

[0167] There may be a case where while the work vehicle **100** is traveling outside the field, there is an obstacle such as a pedestrian or another vehicle on the global path or in the vicinity thereof . In order to avoid the work vehicle **100** colliding against the obstacle, while the work vehicle **100** is traveling, the ECU **185** of the controller **180** consecutively generates a local path along which the work vehicle **100** can avoid the obstacle. While the work vehicle **100** is traveling, the ECU **185** generates a local path based on sensing data acquired by the sensing device included in the work vehicle **100** (the obstacle sensors **130,** the LiDAR sensor **140,** the cameras **120,** etc.). The local path is defined by a plurality of waypoints along a portion of the second path **30B.** Based on the sensing data, the ECU **185** determines whether there is an obstacle existing on the road on which the work vehicle **100** is proceeding or in the vicinity thereof. In the case where there is such an obstacle, the ECU **185** sets a plurality of waypoints such that the obstacle is avoided, and thus generates a local path. In the case where there is no such obstacle, the ECU **185** generates a local path substantially parallel to the second path **30B.** Information representing the generated local path is transmitted to the ECU **184** responsible for self-driving control. The ECU **184** controls the ECU **181** and the ECU **182** such that the work vehicle **100** travels along the local path. This allows the work vehicle **100** to travel while avoiding the obstacle. In the case where there is a traffic signal on the road on which the work vehicle **100** is traveling, the work vehicle **100** may recognize the traffic signal based on, for example, an image captured by the cameras **120** and perform an operation of halting at a red light and moving forward at a green light.

[0168] FIG. **27** is a diagram showing an example of global path and an example of local path generated in an environment where there is an obstacle. FIG. **27** represents, as an example, a global path **30** by the broken line arrows, and represents, as an example, local paths **32** consecutively generated during travel of the work vehicle **100** by the solid line arrows. The global path **30** is defined by a plurality of waypoints **30p.** The local paths **32** are defined by a plurality of waypoints **32p** set at a shorter interval than the waypoints **30p.** The waypoints each have information on, for example, the position and the orientation. The management device **600** sets the plurality of waypoints **30p** at a plurality of points including an intersection of the roads **76** to generate the global path **30.** The interval between the waypoints **30p** is relatively long, and may be, for example, about several meters to about several tens of meters. The ECU **185** sets the plurality of waypoints **32p** based on the sensing data output from the sensing device during travel of the work vehicle **100** to generate the local paths **32.** The interval between the waypoints **32p** of the local paths **32** is shorter than the interval between the waypoints **30p** of the global path **30.** The interval between the waypoints **32p** may be, for example, about several tens of centimeters (cm) to about several meters (m). The local paths **32** are generated in a relatively small range (e.g., a range of about several meters) from the position of the work vehicle **100.** FIG. **27** shows, as an example, a series of local paths **32** generated while the work vehicle **100** travels along the road **76** between the fields **70** and turns left at the intersection. While the work vehicle **100** is moving, the ECU **185** repeats an operation of generating a local path from the position of the work vehicle **100** estimated by the ECU **184** to, for example, a point frontward of the work vehicle **100** by several meters. The work vehicle **100** travels along the local paths consecutively generated.

[0169] In the example shown in FIG. **27,** there is an obstacle **40** (e.g., a human) frontward of the work vehicle **100.** FIG. **27** shows a fan-shaped region as an example of range sensed by the sensing devices such as the cameras **120,** the obstacle sensors **130** or the LiDAR sensor **140** mounted on the work vehicle **100.** In such a state, the ECU **185** generates the local paths **32** such that the obstacle **40** detected based on the sensing data is avoided. The ECU **185** determines whether there is a possibility that the work vehicle **100** will collide against the obstacle **40,** based on, for example, the sensing data and the width of the work vehicle **100** (including the width of the implement in the case where the implement is attached) . In the case where there is a possibility that the work vehicle **100** will collide against the obstacle **40,** the ECU **185** sets the plurality of waypoints **32p** such that the obstacle **40** is avoided, and generates the local paths **32.** Note that the ECU **185** may recognize the state of the road surface (e.g. , being muddy, having a cave-in, etc.) based on the sensing data, in addition to the presence/absence of the obstacle **40,** and in the case where a site on which it is difficult to walk is detected, may generate the local paths **32** such that the local path **32** avoids such a site. The work vehicle **100** travels along the local paths **32.** In the case where the obstacle **40** cannot be avoided in whichever manner the local paths **32** may be set, the controller **180** may halt the work vehicle **100.** At this point, the controller **180** may transmit an alert signal to the terminal device **400** to warn a supervisor. In the case where after the work vehicle **100** halts, the obstacle **40** is moved and it is recognized that there is no risk of collision, the controller **180** may restart the travel of the work vehicle **100.**

[0170] FIG. **28** is a flowchart showing an operation of path planning and travel control according to the present embodiment. An operations of steps **S141** to **S146** shown in FIG. **28** is performed, so that the path planning can be performed and the self-traveling of the work vehicle **100** can be controlled.

[0171] In the example shown in FIG. **28,** the management device **600** first acquires a map and a work plan from the storage device **650** (step **S141**). Next, the management device **600** performs global path planning for the work vehicle **100** based on the map and the work plan by the above-described method (step **S142**). The global path planning may be performed at any timing before the work vehicle **100** begins to travel. The global path planning may be performed immediately before the work vehicle **100** begins to travel, or the day before the work vehicle **100** begins to travel or even earlier. The global path may be generated based on information input by the user by use of the terminal device **400** (e.g., based on the departure point, the target point, the waypoints, etc.). As described above, for generation of a path toward a field or a path from a field toward another site (e.g., the repository or the waiting area for the work vehicle **100**), the management device **600** generates at least one of a path including an agricultural road with priority, a path including a road along a specific feature with priority, or a path including, with priority, a road where satellite signals can be properly received. The management device **600** generates at least one of these paths as the path for the work vehicle **100** based on the attribute information on each road on the map. The management device **600** transmits the data representing the generated global path to the work vehicle **100.** After this, the management device **600** gives the work vehicle **100** a command to travel, at a predetermined timing. Upon receipt of the command, the controller **180** of the work vehicle **100** controls the drive device **240** to begin the travel of the work vehicle **100** (step **S143**). This causes the work vehicle **100**

to begin traveling. The timing when the work vehicle **100** begins traveling may set to, for example, such an appropriate timing as to allow the work vehicle **100** to arrive at the field before the time when the first task of agricultural work is to begin on each working day indicated by the work plan. While the work vehicle **100** is traveling, the ECU **185** of the controller **180** performs local path planning in order to avoid the collision of the work vehicle **100** and the obstacle by the above-described method (step **S144**). In the case where no obstacle is detected, the ECU **185** generates the local paths substantially parallel to the global path. In the case where an obstacle is detected, the ECU **185** generates local paths along which the obstacle is avoidable. Next, the ECU **184** determines whether to end the travel of the work vehicle **100** (step **S145**). In the case where, for example, the local paths along which the obstacle is avoidable cannot be generated, or in the case where the work vehicle **100** has arrived at the target point, the ECU **184** halts the work vehicle **100** (step **S146**). In the case where no obstacle is detected, or in the case where the local paths along which the obstacle is avoidable is generated, the operation returns to step **S143,** where the ECU **184** causes the work vehicle **100** to travel along the generated local paths. After this, the operation in steps **S143** to **S145** is repeated until it is determined in step **S145** to end the travel.

[0172] With the above-described operation, the work vehicle **100** can automatically travel along the generated paths without colliding against any obstacle.

[0173] In the example shown in FIG. **28,** the global path, once generated, is not changed until the work vehicle **100** arrives at the target point. The global path is not limited to this, and may be modified while the work vehicle **100** is traveling. For example, the ECU **185** may recognize at least one of the state of the road on which the work vehicle **100** is traveling, the state of the plants in the surroundings of the work vehicle **100,** or the state of weather, based on the sensing data acquired by the sensing devices such as the cameras **120** or the LiDAR sensor **140** while the work vehicle **100** is traveling, and in the case where the recognized state fulfills a predetermined condition, may change the global path. There is a case where while the work vehicle **100** is traveling along the global path, a portion of the road along the global path is difficult to pass along. For example, there is a case where the road is muddy due to a heavy rain, the road surface has a cave-in, or it is impossible to pass along the road due to an accident or any other reason. Alternatively, there is a case where a satellite signal from a GNSS satellite is difficult to be received for the reason that the plants around the agricultural road have grown more than expected or that a new building has been built. In consideration of such a situation, the ECU **185** may detect a road that is difficult to pass along, based on the sensing data acquired during travel of the work vehicle **100** and may change the path such that the post-change path avoids such a road. In the case where the path is changed, the ECU **185** may cause the storage device **170** to store the post-change path and may transmit information on the post-change path to the management device **600.** In this case, the next time a path to the same field is to be generated, the management device **600** may adopt the post-change path. This allows the path planning to be performed flexibly in accordance with a change in the environment.

(Other embodiments)

[0174] The configurations and operations in the above-described embodiments are merely examples, and the present disclosure is not limited to the above-described embodiments. Hereinafter, other example embodiments will be described.

[0175] In the above-described embodiments, the processor **660** of the management device **600** creates a work plan, generates an environment map, and performs global path planning for the work vehicle **100,** whereas the controller **180** disposed inside the work vehicle **100** performs local path planning and travel control for the work vehicle **100.** Instead of such an embodiment, a portion of the operations assigned to the management device **600** may be performed by the controller **180,** the operational terminal **200** or the terminal device **400.** For example, the generation of the environment map and the generation of the global path may be performed by the controller **180,** the operational terminal **200** or the terminal device **400.**

[0176] The management device **600** may manage the operations of a plurality of agricultural machines including the work vehicle **100.** In this case, the management device **600** may perform global path planning and issue travel instructions for each of the agricultural machines based on the schedule of the agricultural work to be performed by each agricultural machine.

[0177] A system performing the path planning or self-driving control according to the above-described embodiments can be mounted on an agricultural machine lacking such functions, as an add-on. Such a system may be manufactured and marketed independently from the agricultural machine. A computer program for use in such a system may also be manufactured and marketed independently from the agricultural machine. The computer program may be provided in a form stored in a non-transitory computer-readable storage medium, for example. The computer program may also be provided through downloading via telecommunication lines (e.g., the Internet).

[0178] As described above, a path planning system according to an embodiment of the present disclosure is for an agricultural machine to automatically travel inside and outside a field. The path planning system includes a storage device to store a map of a region including a plurality of fields and roads around the plurality of fields; and a processing unit to generate a path for the agricultural machine on the map. The map includes attribute information representing, for each of the roads, at least one of whether the road is an agricultural road, whether the road is a road along a specific feature, or whether the road is a road where satellite signals from GNSS satellites can be properly received. For generation of a path toward a field or a path from a field toward another site, the processing unit generates at least one of a path including an agricultural road with priority, a path including a road along the specific feature with priority, or a path including, with priority, a road where the satellite signals can be properly received, as the path for the agricultural machine based on the attribute information. With this configuration, a path preferred for self - traveling of the agricultural machine can be generated.

[0179] The map may include attribute information representing, for each road, whether the road is a road along a waterway as the specific feature. The processing unit may generate a path including a road along the waterway with priority, as the path for the agricultural machine based on the attribute information. With this configuration, a path including many roads along a waterway, which is preferred as a landmark usable for localization performed by use of a LiDAR sensor or a camera, can be generated.

[0180] The processing unit may determine a path by which an evaluation function is minimum, as the path for the agricultural machine among a plurality of paths reaching a target point from a departure point, the evaluation function being such that a path having a higher ratio of agricultural roads, a higher ratio of roads along the specific feature, or a higher ratio of roads where the satellite signals can be properly received is given a smaller evaluation value and a path providing a longer moving distance or a longer moving time is given a larger evaluation value. With this configuration, a path having a high ratio of agricultural roads, a high ratio of roads along the specific feature or a high ratio of roads where the satellite signals can be properly received can be generated stably.

[0181] The processing unit may generate the path in a mode selected by a user from a plurality of modes including at least one of a first mode to generate the path with an agricultural road being selected with priority, a second mode to generate the path with a road along the specific feature being selected with priority, or a third mode to generate the path with a road where the satellite signals can be properly received being selected with priority. With this configuration, a path reflecting a priority item considered to be important by the user can be generated.

[0182] The processing unit may generate the path in a mode selected by the user from a plurality of modes including all of the first mode, the second mode and the third mode. With this configuration, a path reflecting a priority item considered to be important by the user can be generated among a path including an agricultural road with priority, a path including a road along the specific feature with priority, and a path including, with priority, a road where the satellite signals can be properly received.

[0183] The processing unit may generate the path in a mode selected by the user from the plurality of modes further including a fourth mode to generate the path such that the moving distance or the moving time of the agricultural machine is shortest. With this configuration, a path by which the moving time or the moving distance is shortest can be generated.

[0184] The processing unit may cause a display device to display a graphical user interface (GUI) to allow the user to select one mode from the plurality of modes. With this configuration, the user can select, on the GUI, the mode corresponding to the priority item that he/she considers to be important.

[0185] The storage device may further store a schedule of at least one task of agricultural work to be performed by the agricultural machine on each of working days . The processing unit may generate, based on the schedule, the path such that a final task of agricultural work on each working day is completed before the time when the agricultural work is to end. With this configuration, a path by which the agricultural work can be completed before the time when the agricultural work is to end as indicated by the schedule can be generated.

[0186] The processing unit may generate, based on the schedule, the path such that the agricultural machine arrives at a field where each of tasks of agricultural work is to be performed before the time when the agricultural work is to begin. With this conf iguration, a path by which the agricultural machine can arrive at each of the fields before the time when the agricultural work is to begin as indicated by the schedule can be generated.

[0187] While the agricultural machine is traveling along the path, the processing unit may repeat an operation of generating a local path which is defined by a plurality of waypoints along a portion of the path and along which an obstacle is avoidable, based on data acquired by a sensing device included in the agricultural machine, and of outputting information representing the local path to a controller controlling the traveling of the agricultural machine. With this configuration, the agricultural machine can travel along the local path along which an obstacle is avoided.

[0188] A control system according to another embodiment of the present disclosure includes the path planning system in any one of the above-described embodiments; and a controller to cause the agricultural machine to travel along the path generated by the processing unit.

[0189] An agricultural machine according to still another embodiment of the present disclosure includes the control system in any one of the above-described embodiments; and a sensing device to perform sensing on a surrounding environment of the agricultural machine. The controller causes the agricultural machine to travel along the path generated by the processing unit based on a signal output from the sensing device.

[0190] A path planning method according to still another embodiment of the present disclosure is for an agricultural machine to automatically travel inside and outside a field. The path planning method includes acquiring, from a storage device, a map of a region including a plurality of fields and roads around the plurality of fields, the map including attribute information representing, for each of the roads, at least one of: whether the road is an agricultural road; whether the road is a road along a waterway; and whether the road is a road where satellite signals from GNSS satellites can be properly received; and generating, as a path toward a field or a path from a field toward another site for the agricultural machine on the map, at least one of a path including an agricultural road with priority, a path including a road along the waterway with priority, and a path including, with priority, a road where the satellite signals can be properly received, based on the attribute information.

[0191] A computer program according to still another embodiment of the present disclosure is to perform path planning for an agricultural machine to automatically travel inside and outside a field. The program may be stored in a computer-readable non-transitory storage medium. The program causes a computer to execute: acquiring, from a storage device, a map of a region including a plurality of fields and roads around the plurality of fields, the map including attribute information representing, for each of the roads, at least one of whether the road is an agricultural road, whether the road is a road along a waterway, or whether the road is a road where satellite signals from GNSS satellites can be properly received; and generating, as a path toward a field or a path from a field toward another site for the agricultural machine on the map, at least one of a path including an agricultural road with priority, a path including a road along the waterway with priority, or a path including, with priority, a road where the satellite signals can be properly received, based on the attribute information.

INDUSTRIAL APPLICABILITY

[0192] The techniques according to the present disclosure are applicable to a path planning system for agricultural machines performing self-driving, such as tractors, harvesters, rice transplanters, vehicles for crop management, vegetable transplanters, mowers, seeders, spreaders, or agricultural robots, for example.

REFERENCE SIGNS LIST

[0193] **30:** global path; **32:** local path; **40:** obstacle; **50:** GNSS satellite; **60:** reference station; **70:** field; **71:** entrance/exit; **72:** work area; **74:** headland; **76:** road; **77:** tree; **78:** waterway; **79:** river; **80:** network; **90:** repository; **92:** house of the user; **96:** waiting area; **100:** work vehicle; **101:** vehicle body; **102:** prime mover (engine); **103:** transmission; **104:** wheel; **105:** cabin; **106:** steering device; **107:** driver's seat; **108:** linkage device; **110:** positioning device; **111:** GNSS receiver; **112:** RTK receiver; **115:** inertial measurement unit (IMU); **116:** processing circuit; **120:** camera; **130:** obstacle sensor; **140:** LiDAR sensor; **150:** sensors; **152:** steering wheel sensor; **154:** angle-of-turn sensor **154; 156:** axle sensor; **160:** control system; **170:** storage device **170; 180:** controller; **181-186:** ECU; **190:** communication device; **200:** operational terminal; **210:** operation switches; **220:** buzzer; **240:** drive device; **300:** implement; **340:** drive device; **380:** controller; **390:** communication device; **400:** terminal device; **420:** input device; **430:** display device; **450:** storage device; **460:** processor; **470:** ROM; **480:** RAM; **490:** communication device; **600:** management device; **660:** processor; **670:** storage device; **670:** ROM; **680:** RAM; **690:** communication device

Claims

1. A path planning system for an agricultural machine to automatically travel inside and outside a field, the path planning system comprising:

a storage device to store a map of a region including a plurality of fields and roads around the plurality of fields; and
a processing unit to generate a path for the agricultural machine on the map;
wherein
the map includes attribute information representing, for each of the roads, at least one of: whether the road is an agricultural road, whether the road is a road along a specific feature, or whether the road is a road where satellite signals from GNSS satellites can be properly received; and
for generation of a path toward a field or a path from a field toward another site, the processing unit generates at least one of a path including an agricultural road with priority, a path including a road along the specific feature with priority, or a path including, with priority, a road where the satellite signals can be properly received, as the path for the agricultural machine based on the attribute information.

2. The path planning system of claim 1, wherein:

the map includes attribute information representing, for each road, whether the road is a road along a waterway

as the specific feature, and
the processing unit generates a path including a road along the waterway with priority, as the path for the agricultural machine based on the attribute information.

3. The path planning system of claim 1, wherein the processing unit determines a path by which an evaluation function is minimum, as the path for the agricultural machine among a plurality of paths reaching a target point from a departure point, the evaluation function being such that a path having a higher ratio of agricultural roads, a higher ratio of roads along the specific feature, or a higher ratio of roads where the satellite signals can be properly received is given a smaller evaluation value and a path providing a longer moving distance or a longer moving time is given a larger evaluation value.

4. The path planning system of any one of claims 1 to 3, wherein the processing unit generates the path in a mode selected by a user from a plurality of modes including at least one of:

a first mode to generate the path with an agricultural road being selected with priority,
a second mode to generate the path with a road along the specific feature being selected with priority, or
a third mode to generate the path with a road where the satellite signals can be properly received being selected with priority.

5. The path planning system of claim 4, wherein the processing unit generates the path in a mode selected by the user from a plurality of modes including all of the first mode, the second mode and the third mode.

6. The path planning system of claim 4 or 5, wherein the processing unit generates the path in a mode selected by the user from the plurality of modes further including a fourth mode to generate the path such that the moving distance or the moving time of the agricultural machine is shortest.

7. The path planning system of any one of claims 4 to 6, wherein the processing unit causes a display device to display a graphical user interface to allow the user to select one mode from the plurality of modes.

8. The path planning system of any one of claims 1 to 7, wherein:

the storage device further stores a schedule of at least one task of agricultural work to be performed by the agricultural machine on each of working days, and
the processing unit generates, based on the schedule, the path such that a final task of agricultural work on each working day is completed before the time when the agricultural work is to end.

9. The path planning system of claim 8, wherein the processing unit generates, based on the schedule, the path such that the agricultural machine arrives at a field where each of tasks of agricultural work is to be performed before the time when the agricultural work is to begin.

10. The path planning system of any one of claims 1 to 9, wherein while the agricultural machine is traveling along the path, the processing unit repeats an operation of generating a local path which is defined by a plurality of waypoints along a portion of the path and along which an obstacle is avoidable, based on data acquired by a sensing device included in the agricultural machine, and of outputting information representing the local path to a controller controlling the traveling of the agricultural machine.

11. A control system, comprising:

the path planning system of any one of claims 1 to 10; and
a controller to cause the agricultural machine to travel along the path generated by the processing unit.

12. An agricultural machine, comprising:

the control system of claim 11; and
a sensing device to perform sensing on a surrounding environment of the agricultural machine;
wherein the controller causes the agricultural machine to travel along the path generated by the processing unit based on a signal output from the sensing device.

13. A path planning method for an agricultural machine to automatically travel inside and outside a field, the path planning method comprising:

acquiring, from a storage device, a map of a region including a plurality of fields and roads around the plurality of fields, the map including attribute information representing, for each of the roads, at least one of whether the road is an agricultural road, whether the road is a road along a waterway, or whether the road is a road where satellite signals from GNSS satellites can be properly received; and
generating, as a path toward a field or a path from a field toward another site for the agricultural machine on the map, at least one of a path including an agricultural road with priority, a path including a road along the waterway with priority, or a path including, with priority, a road where the satellite signals can be properly received, based on the attribute information.

FIG. 1

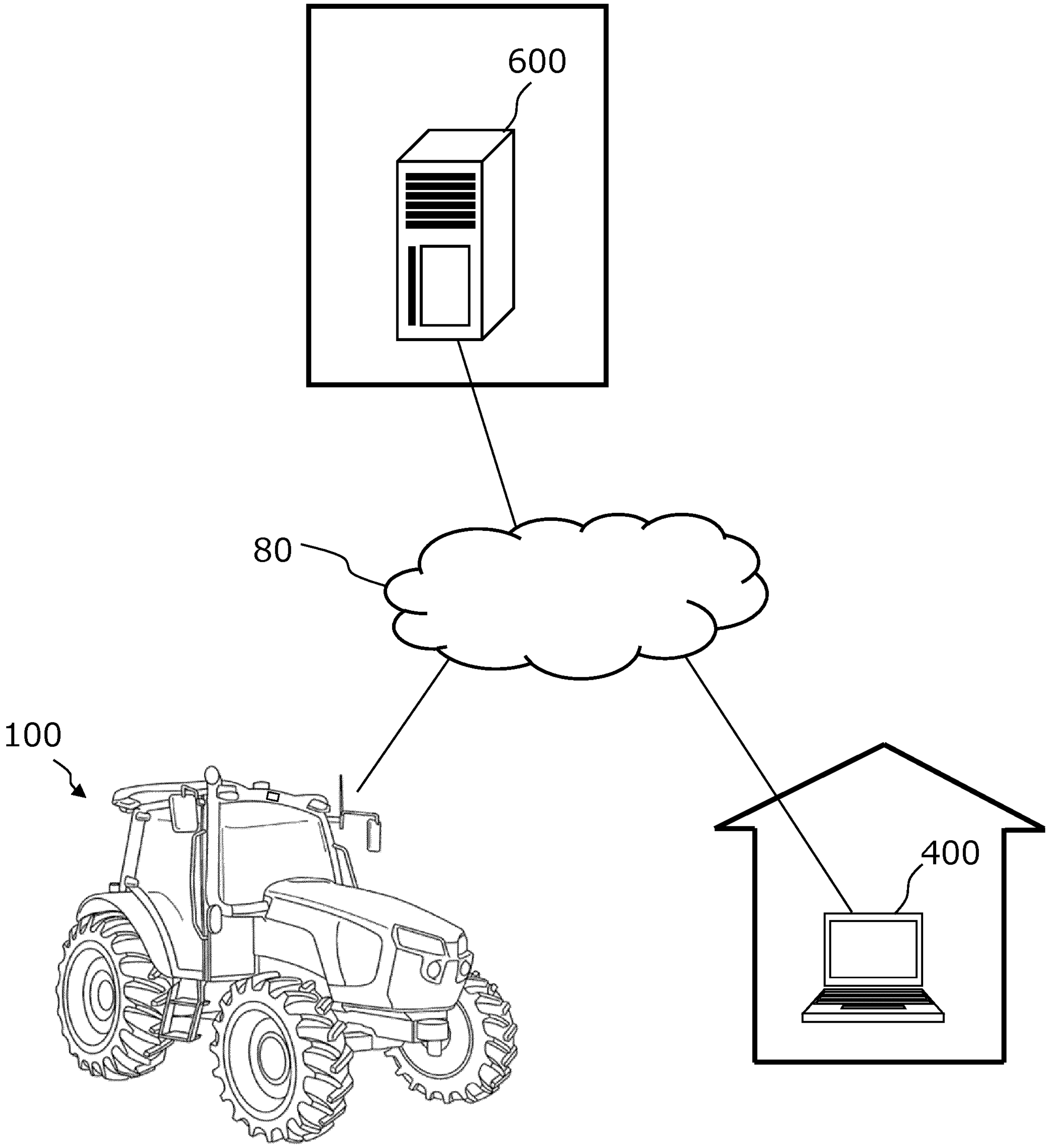


FIG. 2

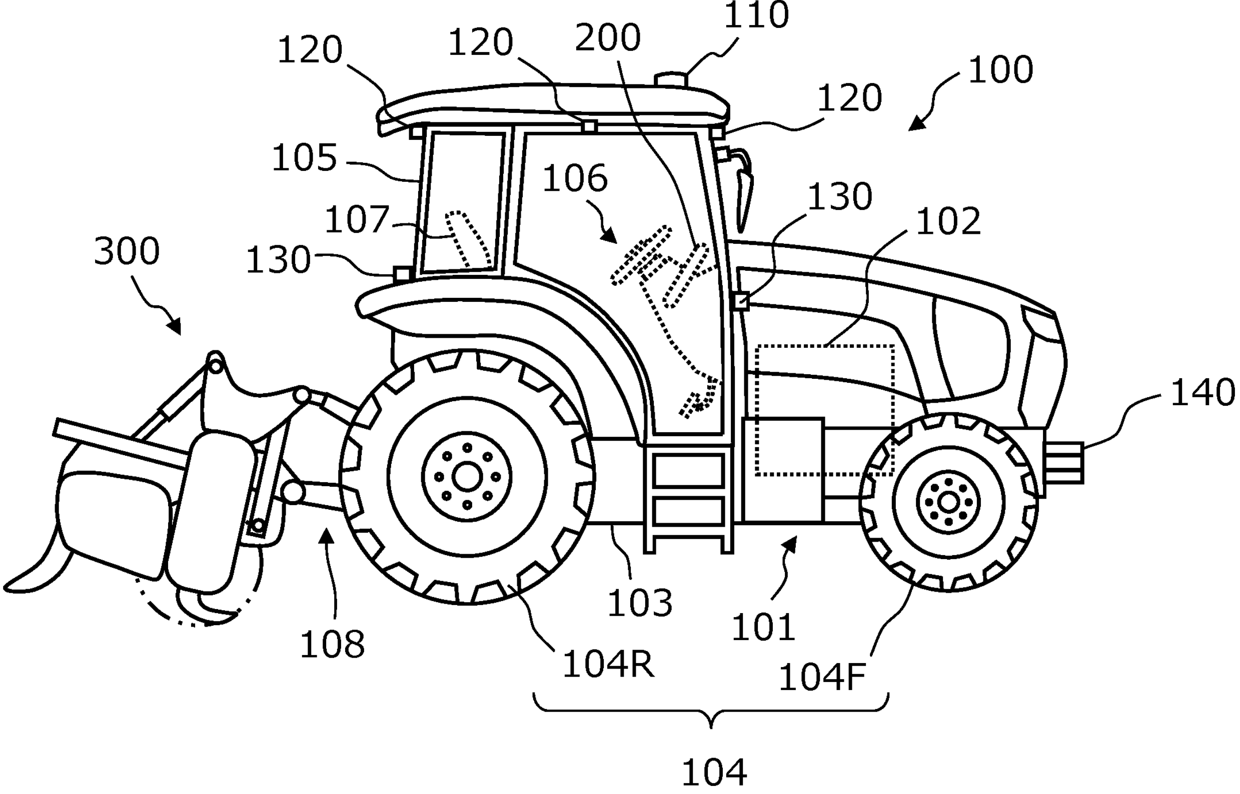

120
120
200
110
100
120
105
106
130
107
102
300
130
140
103
101
108
104R
104F
104

FIG. 3

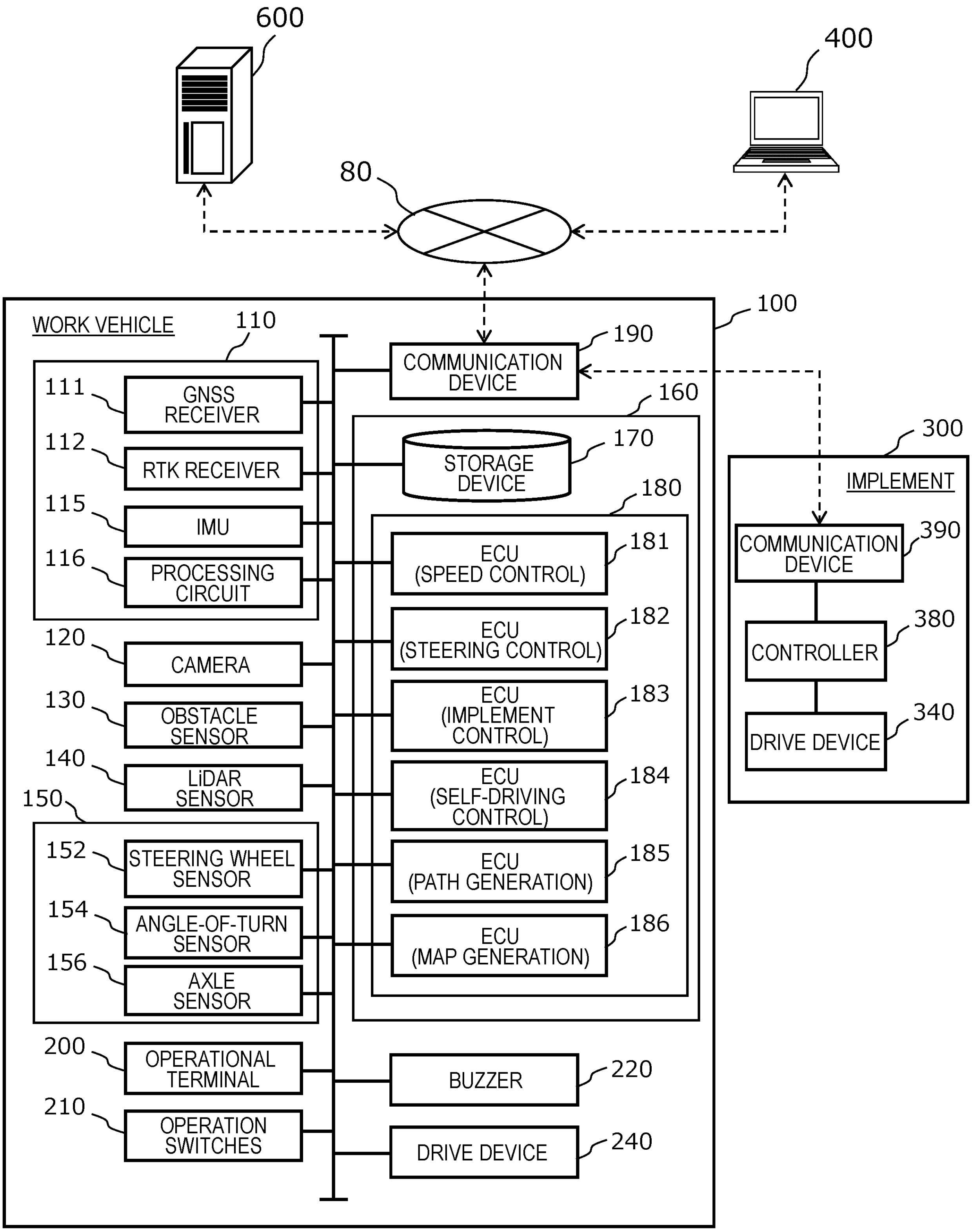

600
400
80
WORK VEHICLE
100
110
190
COMMUNICATION DEVICE
111
GNSS RECEIVER
160
112
RTK RECEIVER
170
STORAGE DEVICE
300
IMPLEMENT
115
IMU
180
116
PROCESSING CIRCUIT
ECU (SPEED CONTROL)
181
COMMUNICATION DEVICE
390
ECU (STEERING CONTROL)
182
380
CONTROLLER
120
CAMERA
130
OBSTACLE SENSOR
ECU (IMPLEMENT CONTROL)
183
340
DRIVE DEVICE
140
LiDAR SENSOR
ECU (SELF-DRIVING CONTROL)
184
150
152
STEERING WHEEL SENSOR
ECU (PATH GENERATION)
185
154
ANGLE-OF-TURN SENSOR
186
ECU (MAP GENERATION)
156
AXLE SENSOR
200
OPERATIONAL TERMINAL
BUZZER
220
210
OPERATION SWITCHES
DRIVE DEVICE
240

FIG. 4

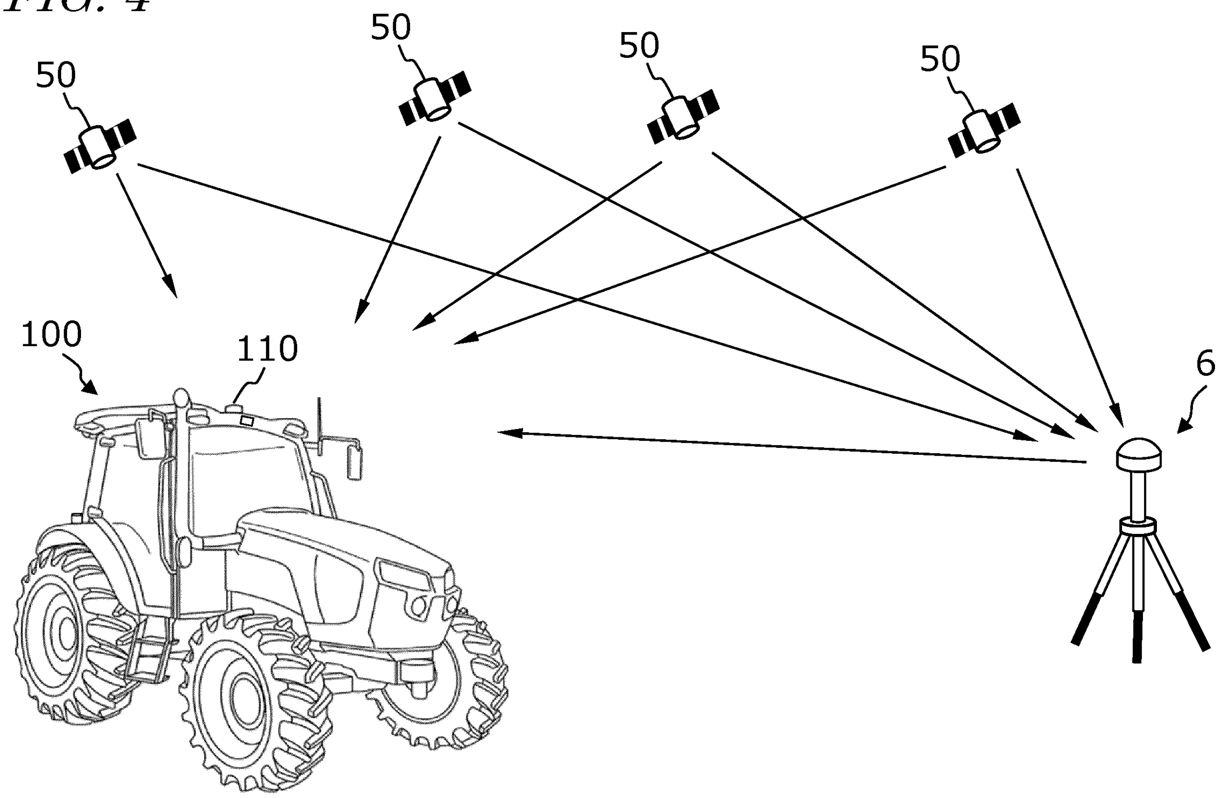


FIG. 5

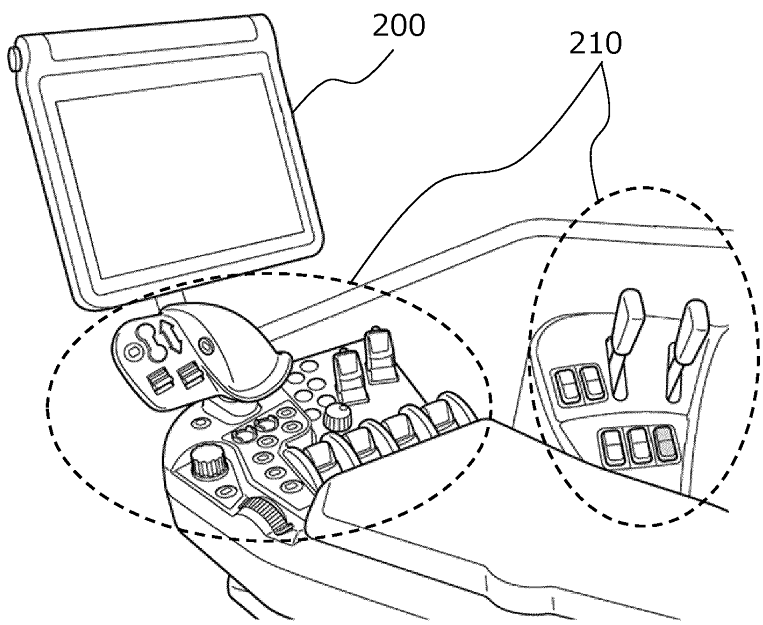


FIG. 6

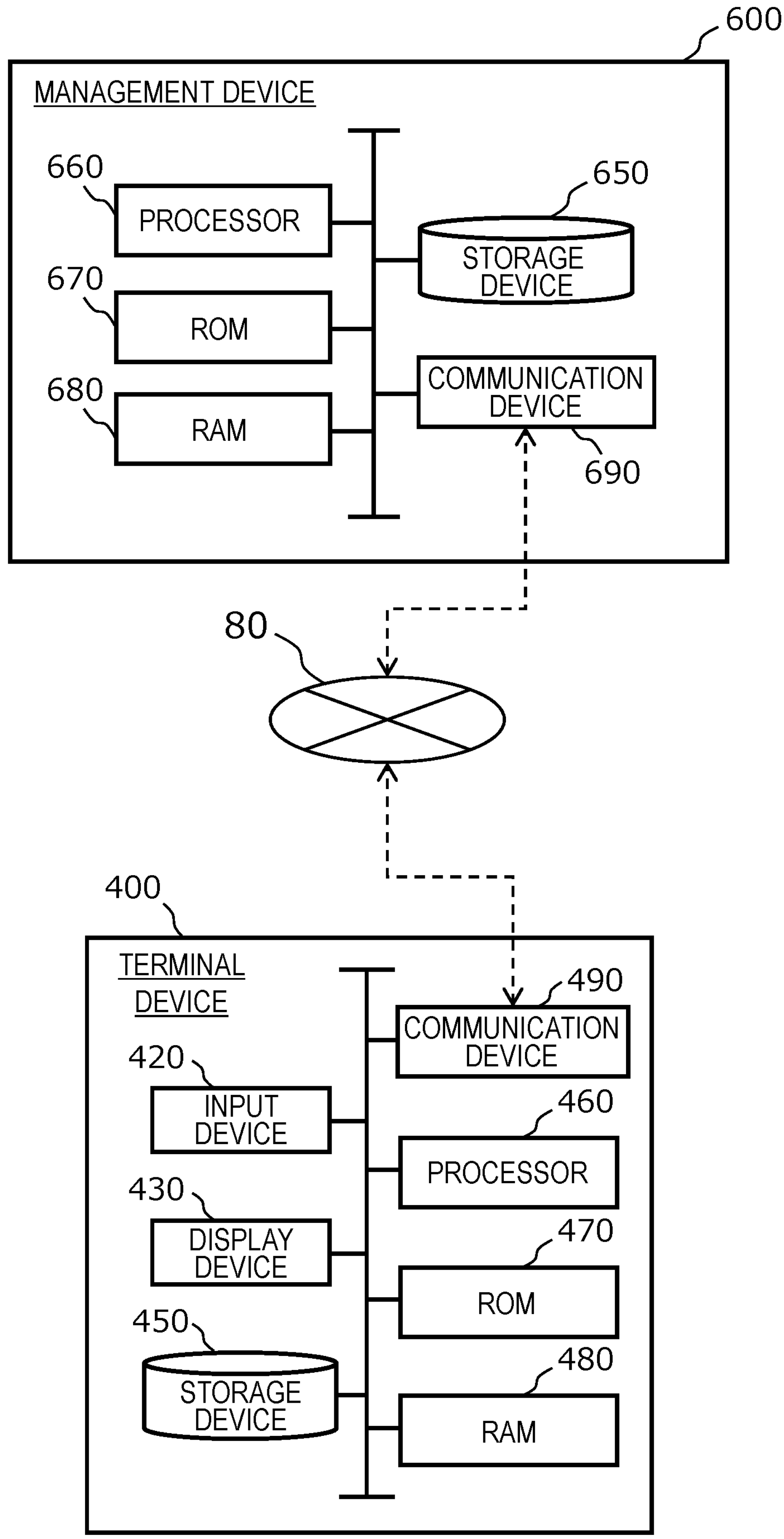

600
MANAGEMENT DEVICE
660
PROCESSOR
650
STORAGE DEVICE
670
ROM
680
RAM
COMMUNICATION DEVICE
690
80
400
TERMINAL DEVICE
490
COMMUNICATION DEVICE
420
INPUT DEVICE
460
PROCESSOR
430
DISPLAY DEVICE
470
ROM
450
STORAGE DEVICE
480
RAM

FIG. 7

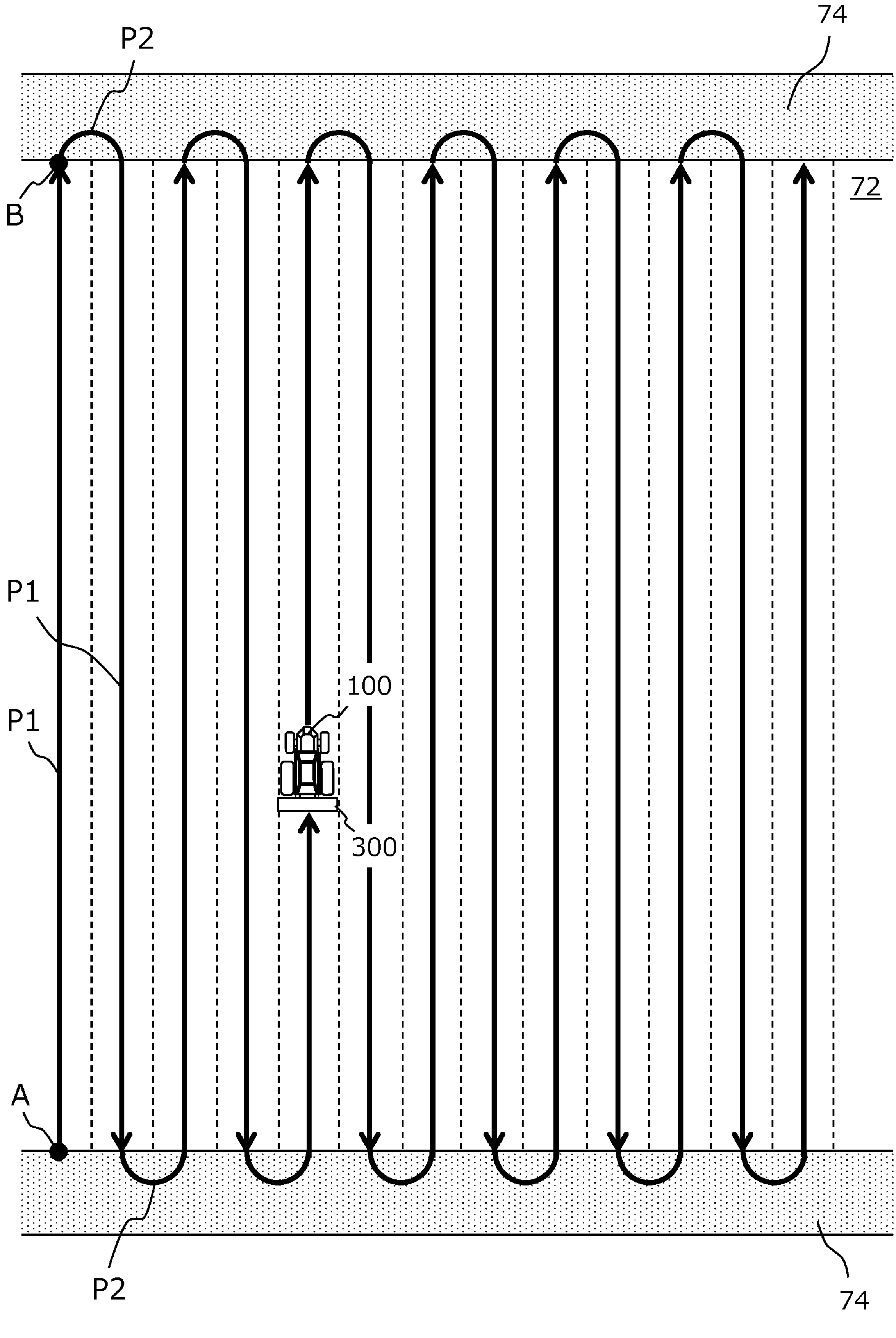


FIG. 8

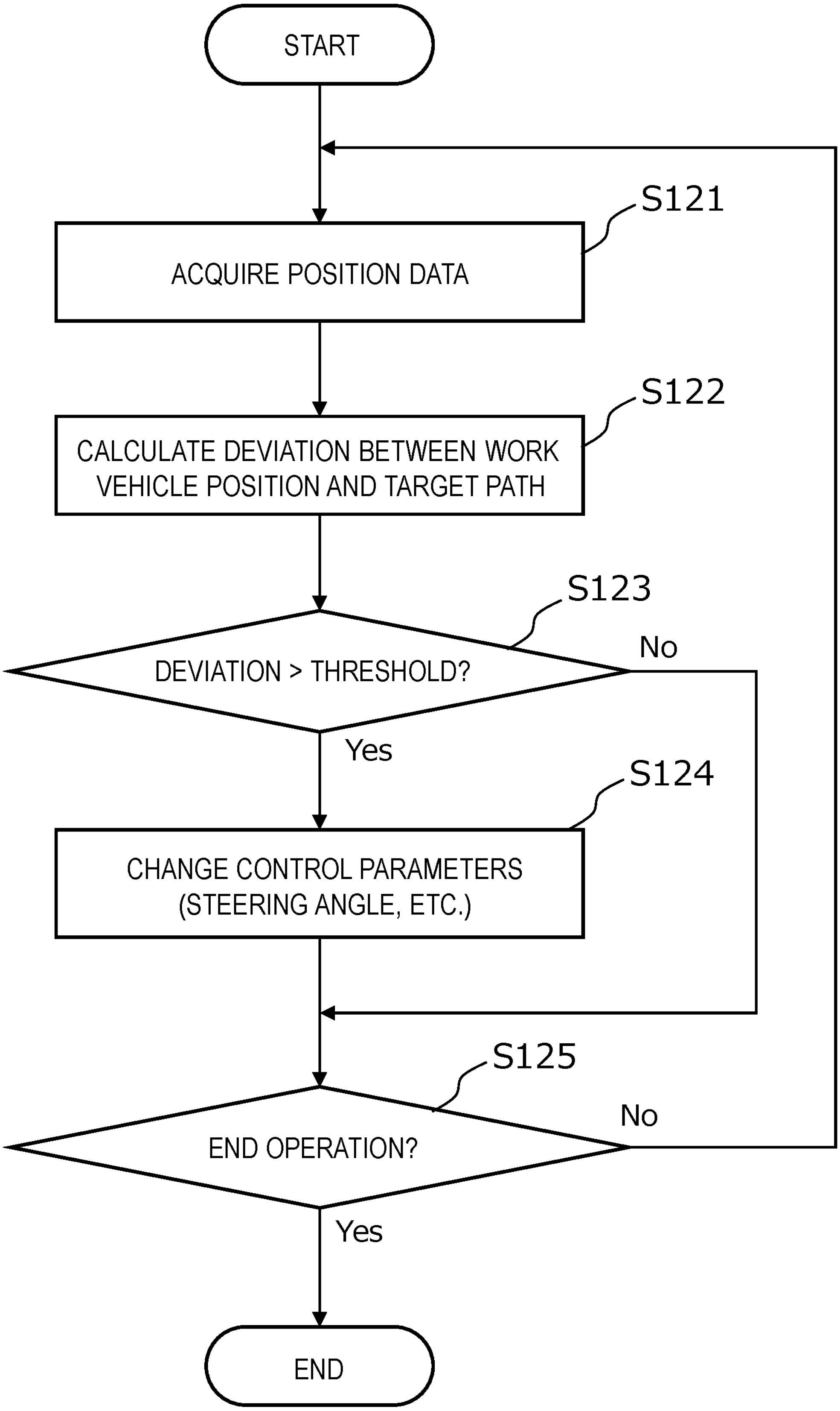

START
S121
ACQUIRE POSITION DATA
S122
CALCULATE DEVIATION BETWEEN WORK VEHICLE POSITION AND TARGET PATH
S123
DEVIATION > THRESHOLD?
No
Yes
S124
CHANGE CONTROL PARAMETERS (STEERING ANGLE, ETC.)
S125
END OPERATION?
No
Yes
END

FIG. 9A

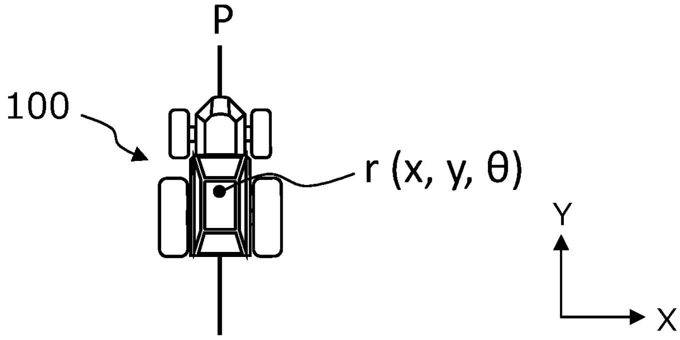


FIG. 9B

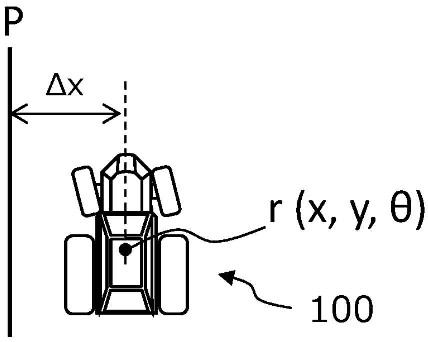


FIG. 9C

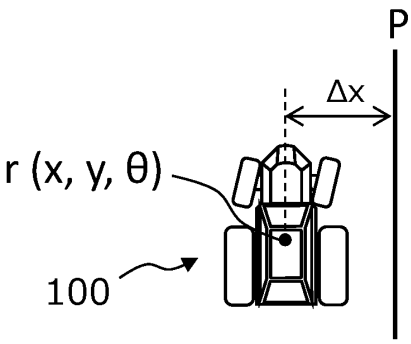


FIG. 9D

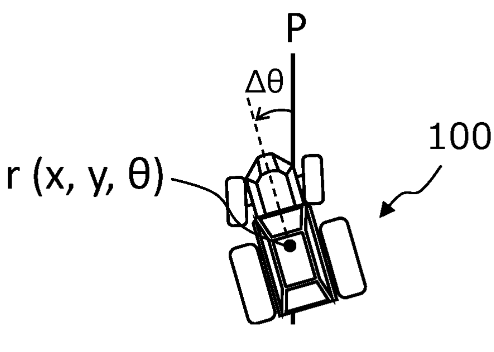


FIG. 10

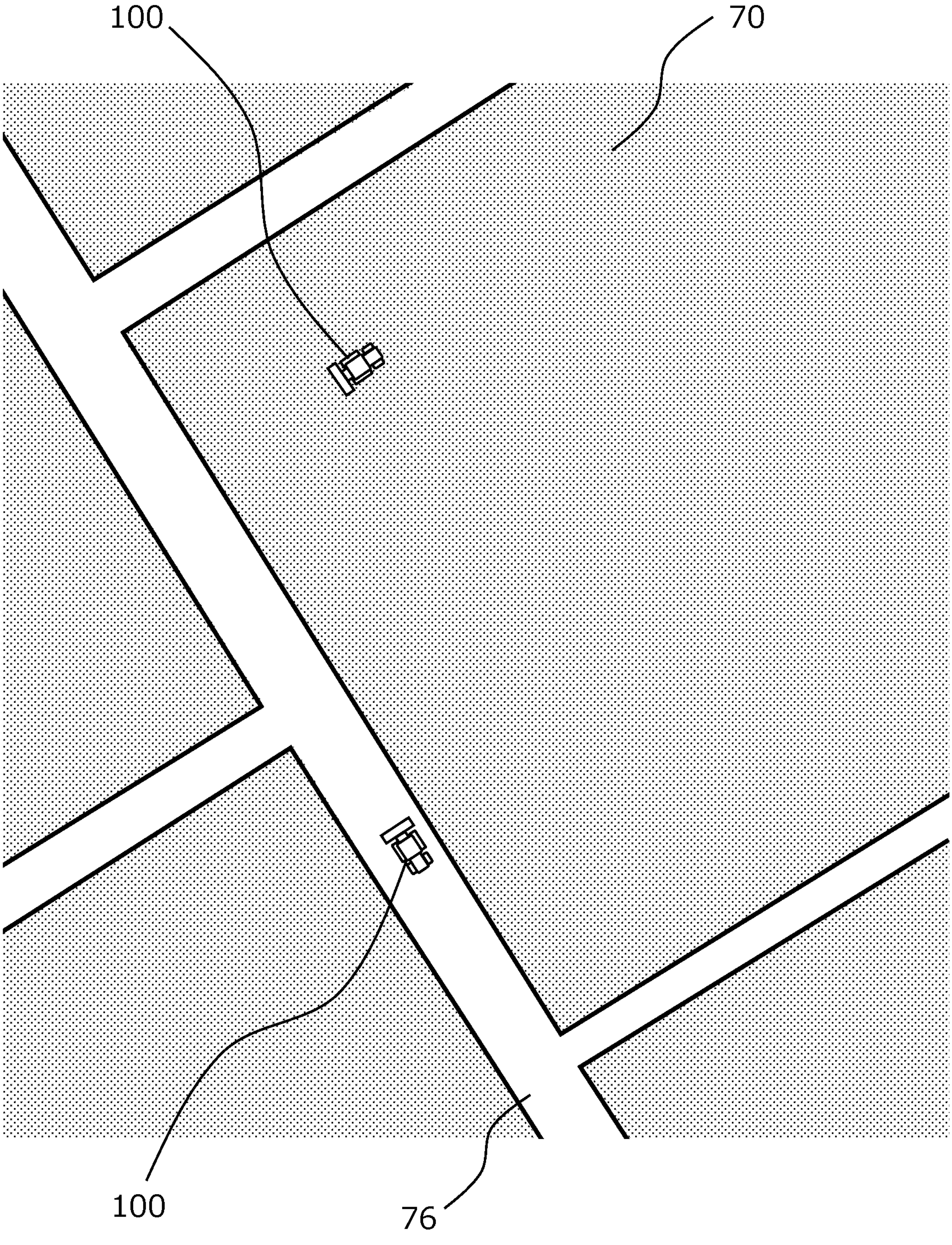


FIG. 11

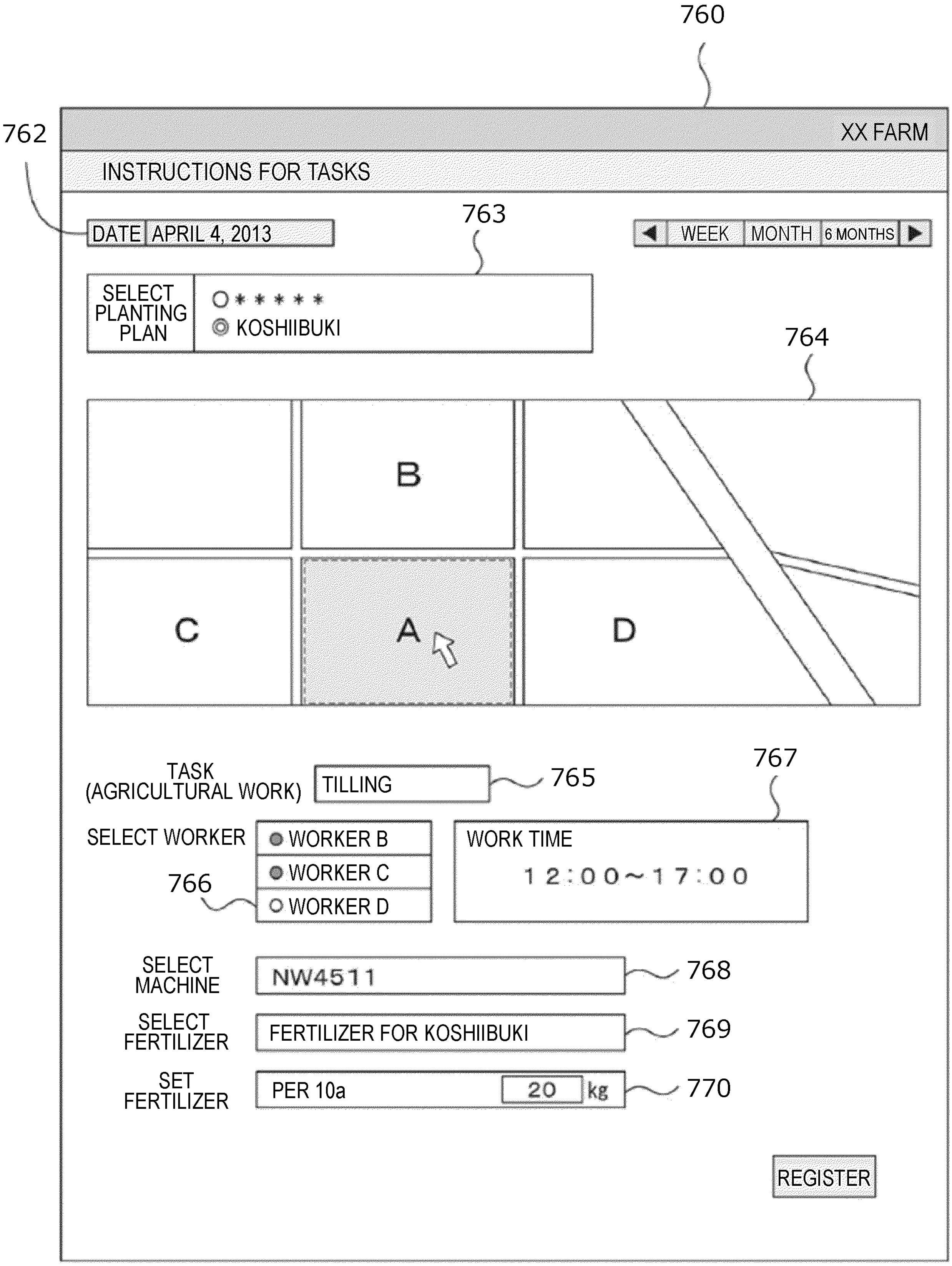

760
762
XX FARM
INSTRUCTIONS FOR TASKS
DATE APRIL 4, 2013
763
WEEK
MONTH
6 MONTHS
SELECT PLANTING PLAN
＊＊＊＊＊＊
KOSHIIBUKI
764
B
C
A
D
TASK (AGRICULTURAL WORK)
TILLING
765
767
SELECT WORKER
WORKER B
WORKER C
WORKER D
766
WORK TIME
12:00~17:00
SELECT MACHINE
NW4511
768
SELECT FERTILIZER
FERTILIZER FOR KOSHIIBUKI
769
SET FERTILIZER
PER 10a
20
kg
770
REGISTER

FIG. 12

AGRICULTURAL MACHINE	DATE/TIME	FIELD	TASK	IMPLEMENT
AGRICULTURAL MACHINE A	JUNE 21, 2021, 8:00 – 11:00	FIELD A	SPRAYING AGRICULTURAL CHEMICALS	IMPLEMENT A
AGRICULTURAL MACHINE A	JUNE 21, 2021, 12:00 – 14:00	FIELD B	SPRAYING AGRICULTURAL CHEMICALS	IMPLEMENT A
AGRICULTURAL MACHINE A	JUNE 21, 2021, 15:00 – 18:00	FIELD C	TILLING	IMPLEMENT B
AGRICULTURAL MACHINE A	JUNE 22, 2021, 8:00 – 12:00	FIELD D	TILLING	IMPLEMENT B
⋮	⋮	⋮	⋮	⋮

FIG. 13

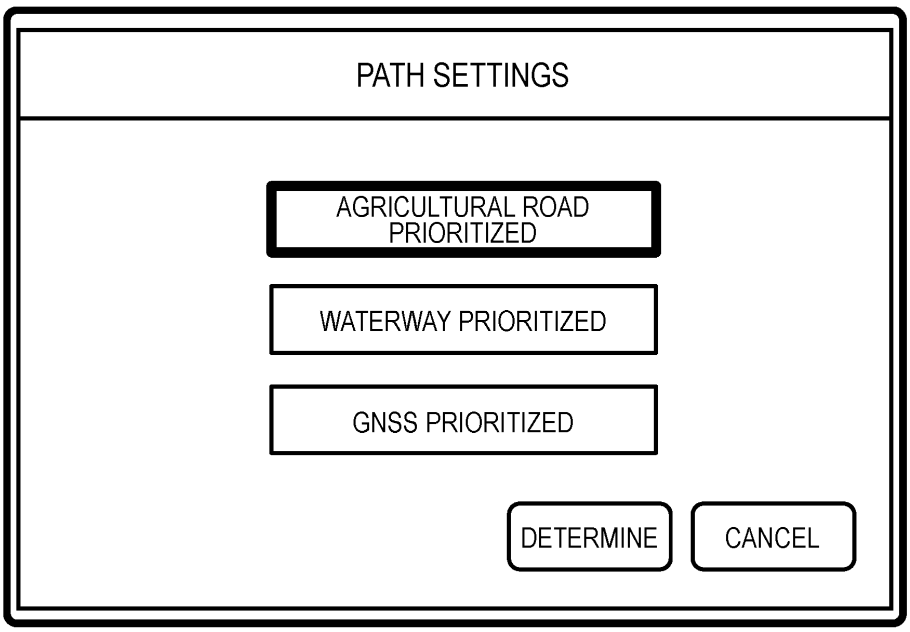


FIG. 14

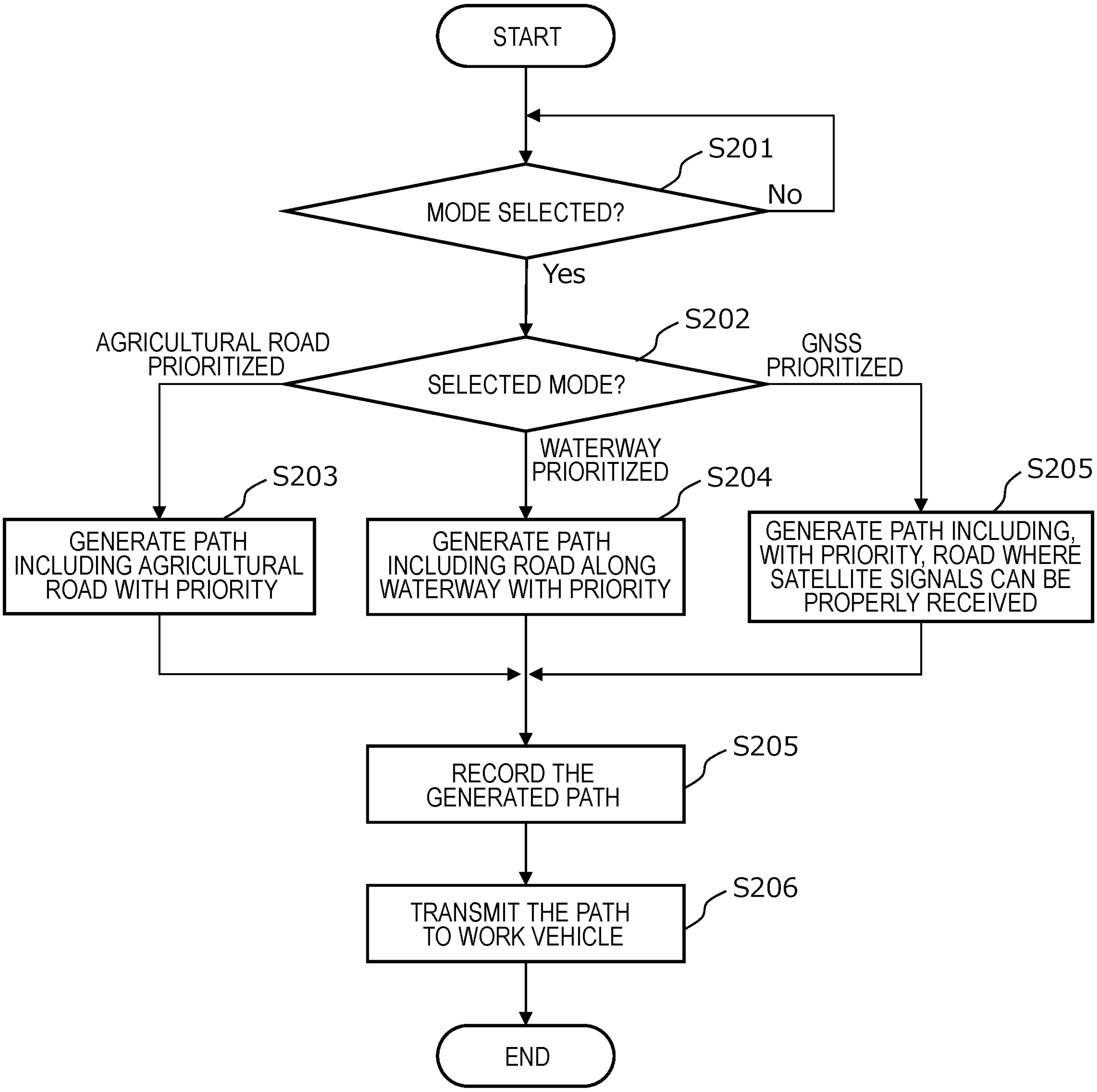

START
S201
MODE SELECTED?
No
Yes
S202
AGRICULTURAL ROAD PRIORITIZED
SELECTED MODE?
GNSS PRIORITIZED
WATERWAY PRIORITIZED
S203
S204
S205
GENERATE PATH INCLUDING AGRICULTURAL ROAD WITH PRIORITY
GENERATE PATH INCLUDING ROAD ALONG WATERWAY WITH PRIORITY
GENERATE PATH INCLUDING, WITH PRIORITY, ROAD WHERE SATELLITE SIGNALS CAN BE PROPERLY RECEIVED
S205
RECORD THE GENERATED PATH
S206
TRANSMIT THE PATH TO WORK VEHICLE
END

FIG. 15

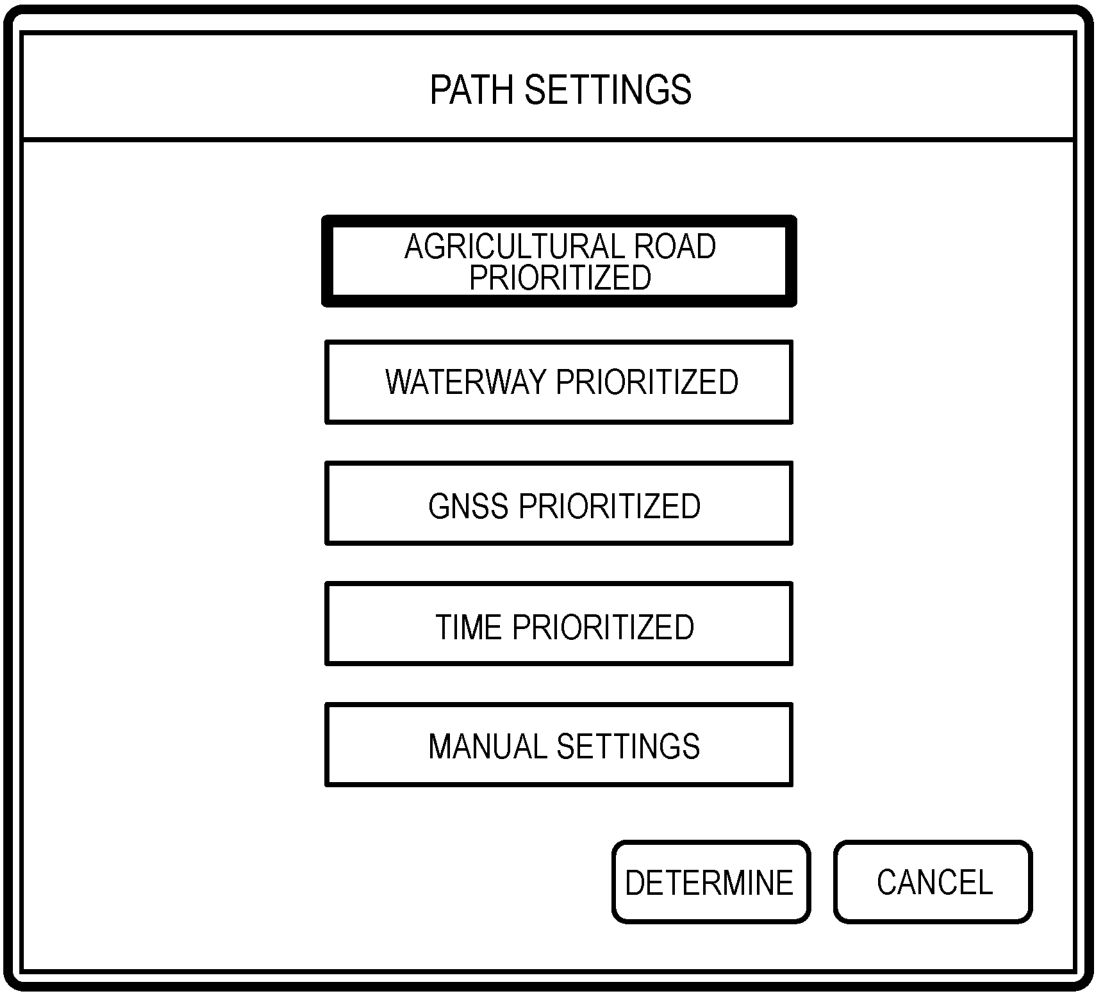

PATH SETTINGS
AGRICULTURAL ROAD PRIORITIZED
WATERWAY PRIORITIZED
GNSS PRIORITIZED
TIME PRIORITIZED
MANUAL SETTINGS
DETERMINE
CANCEL

FIG. 16

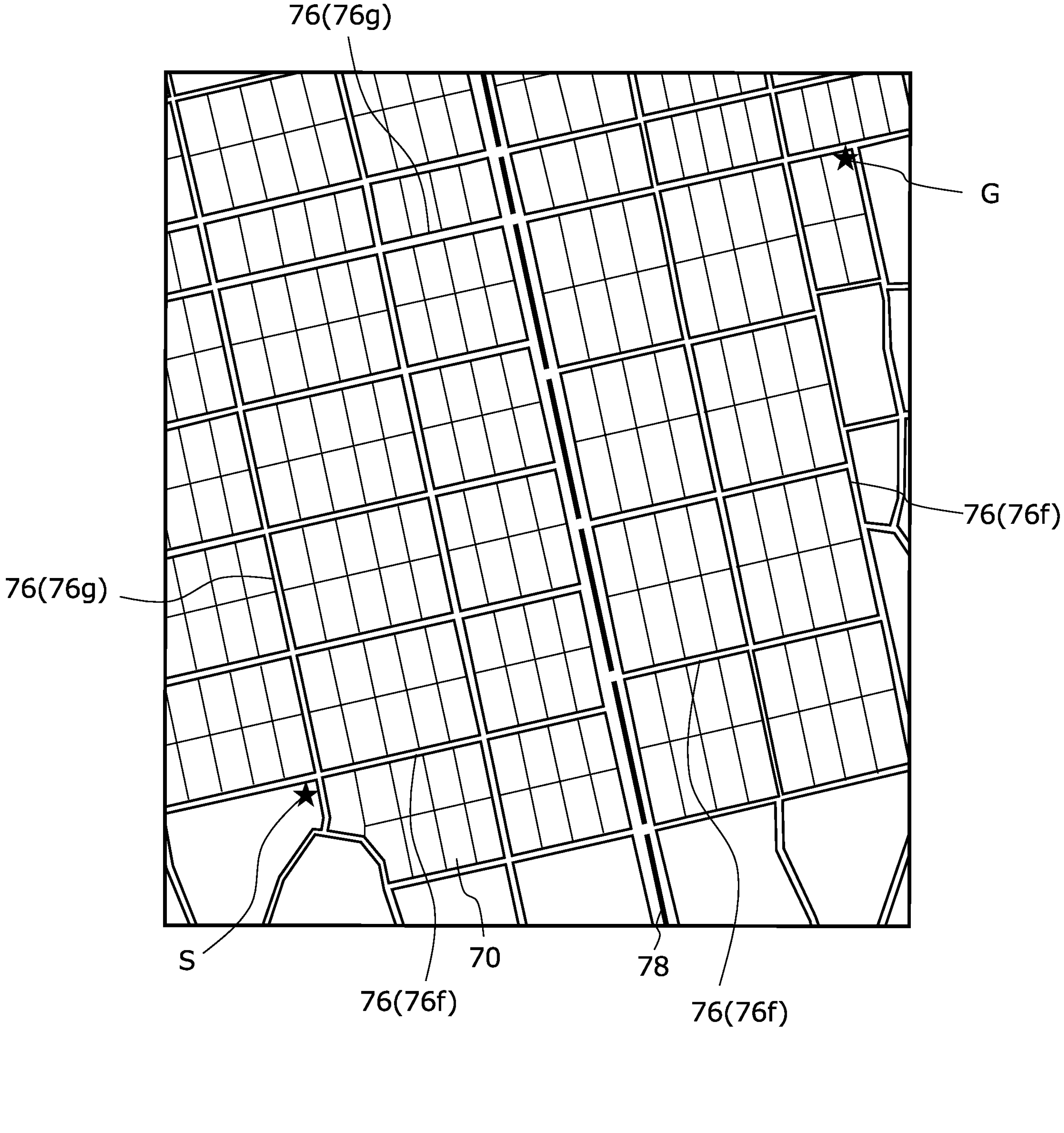


FIG. 17

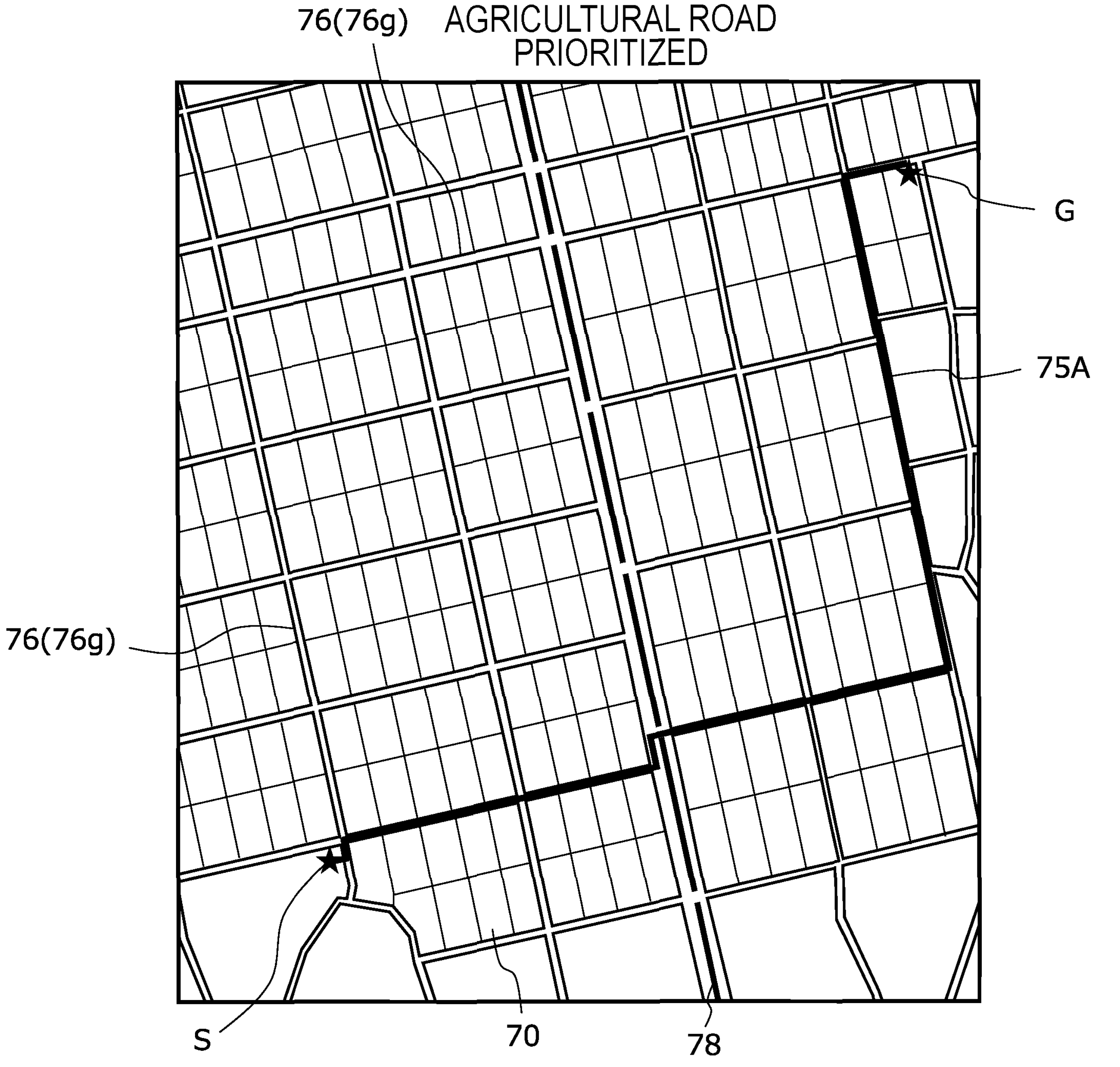


FIG. 18

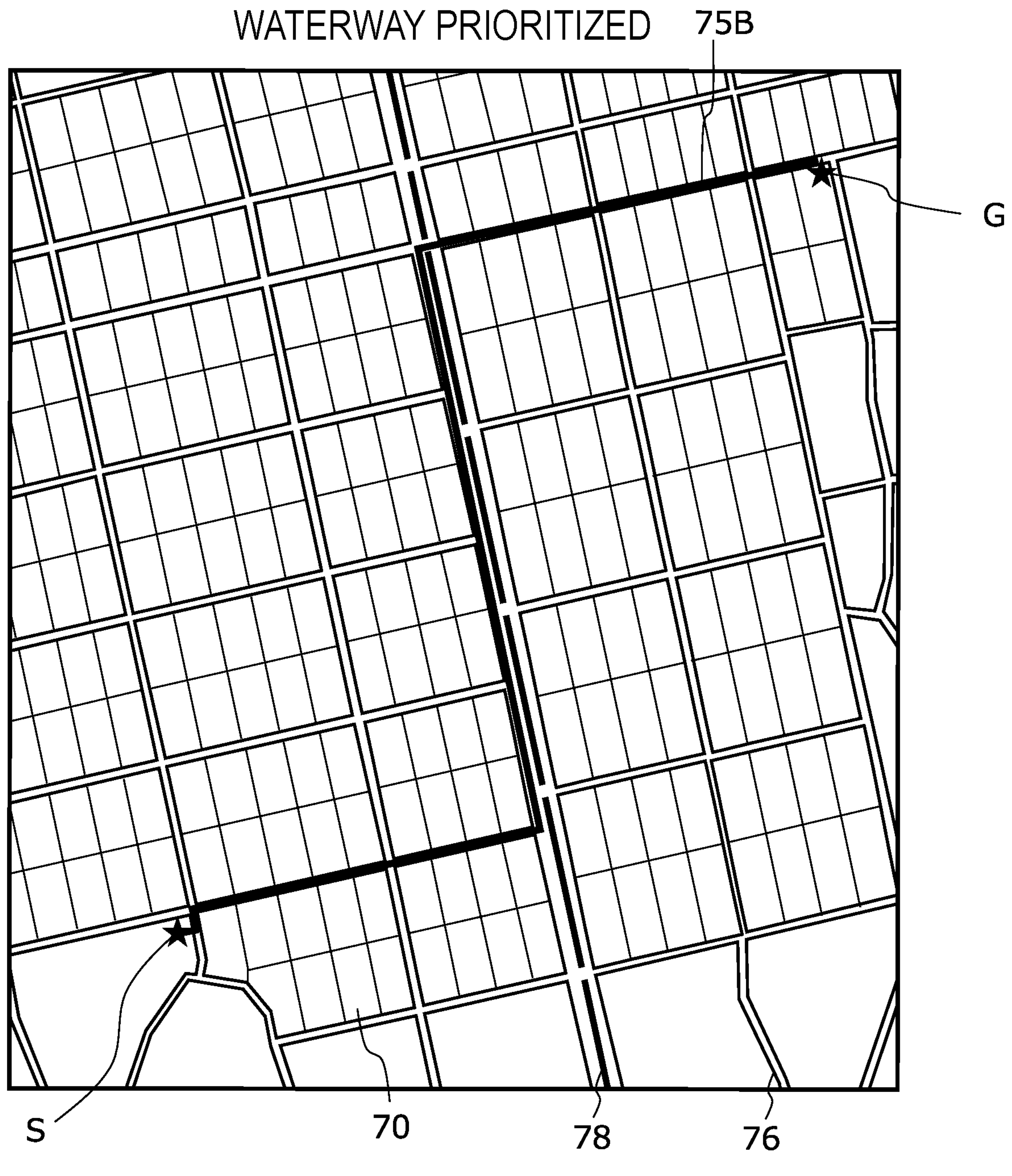


FIG. 19

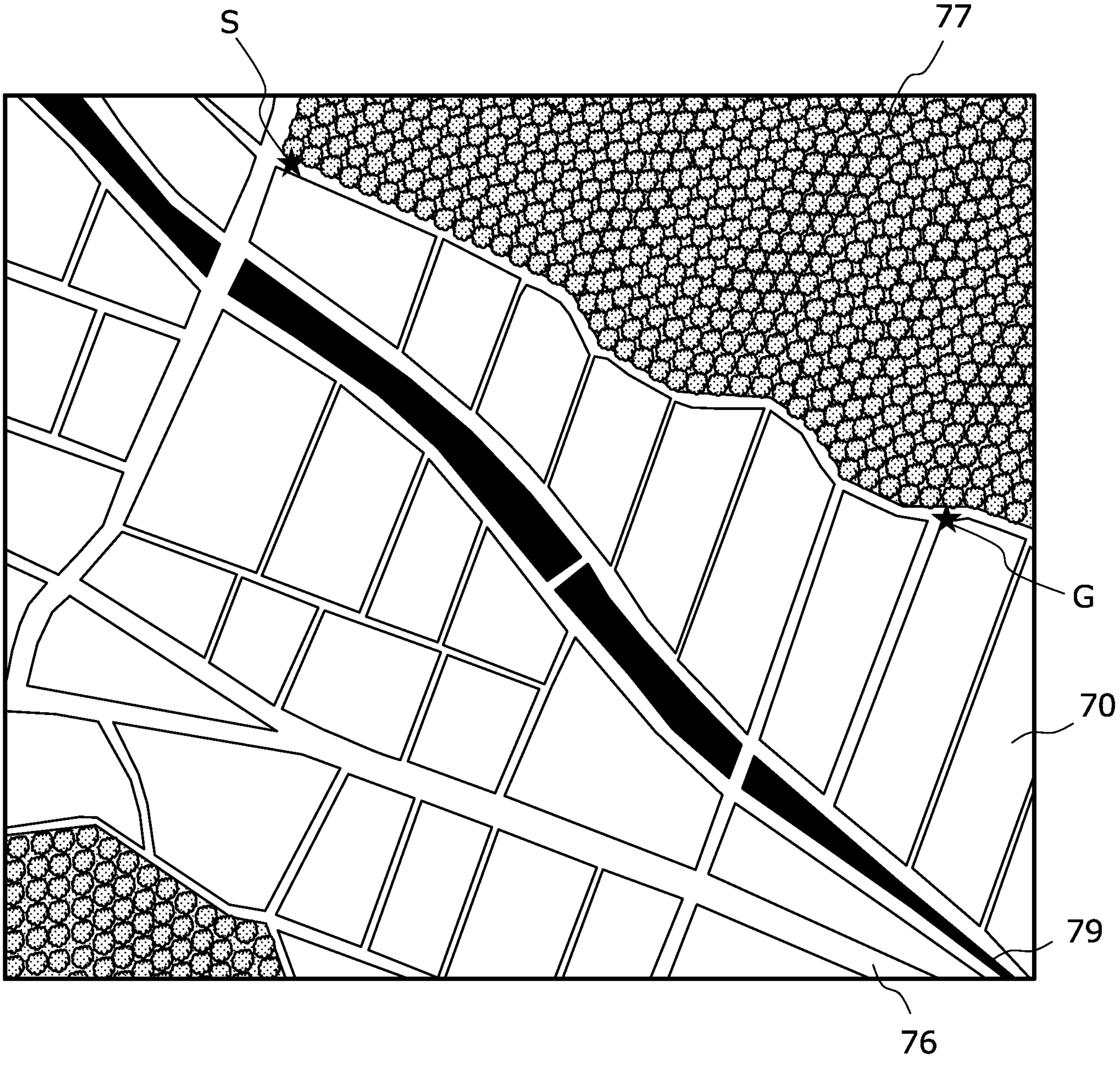


FIG. 20

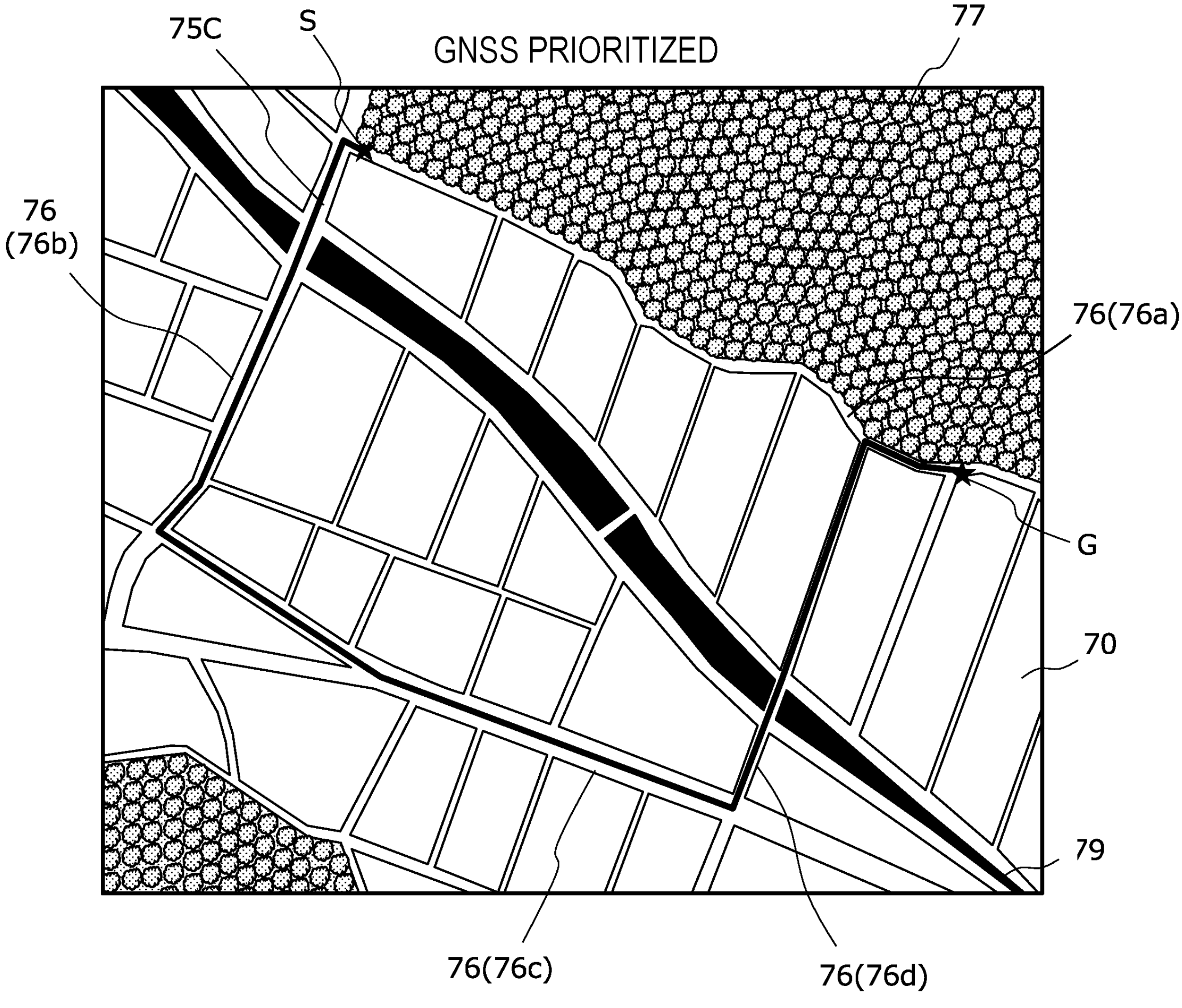


FIG. 21

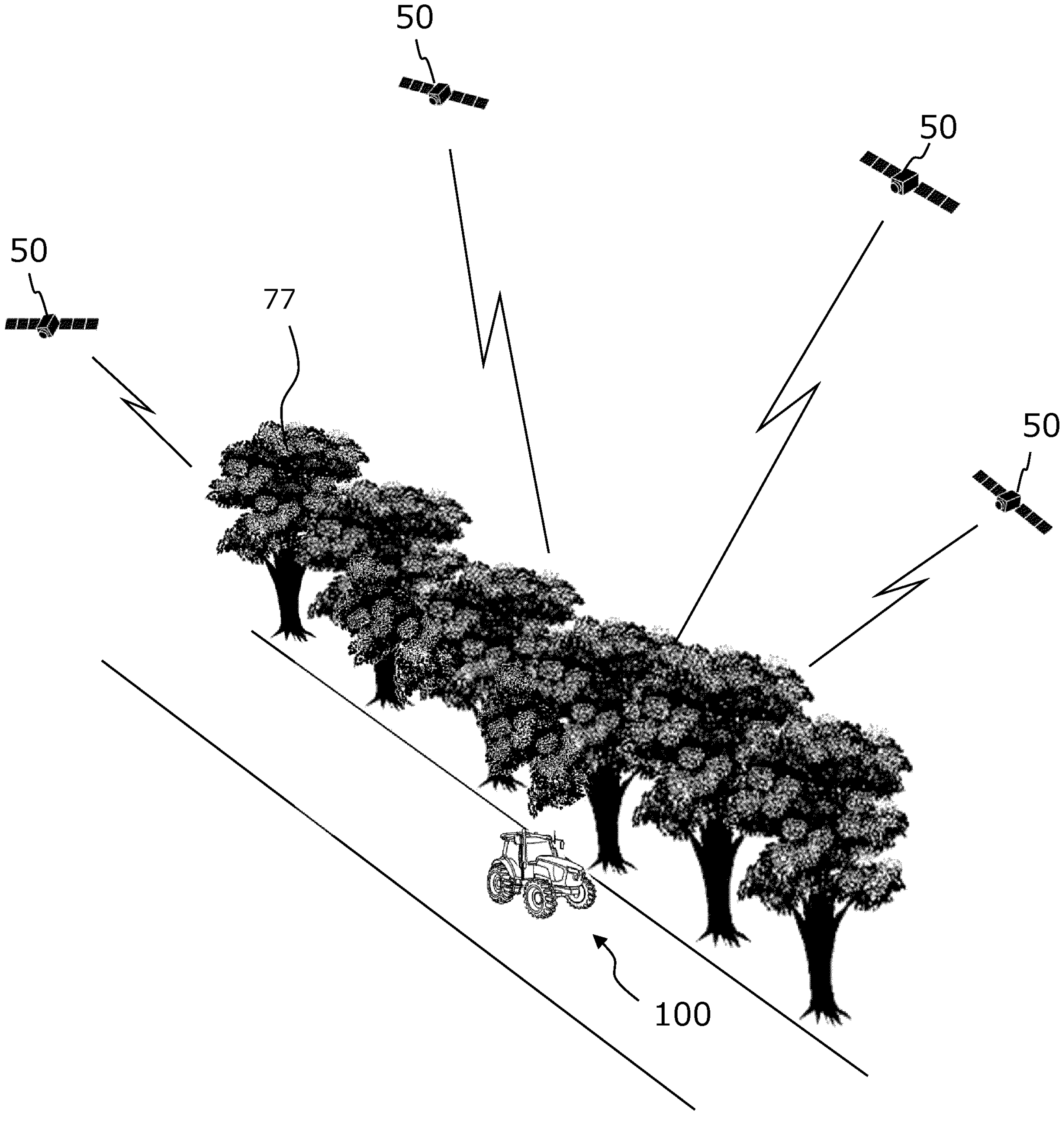


FIG. 22A

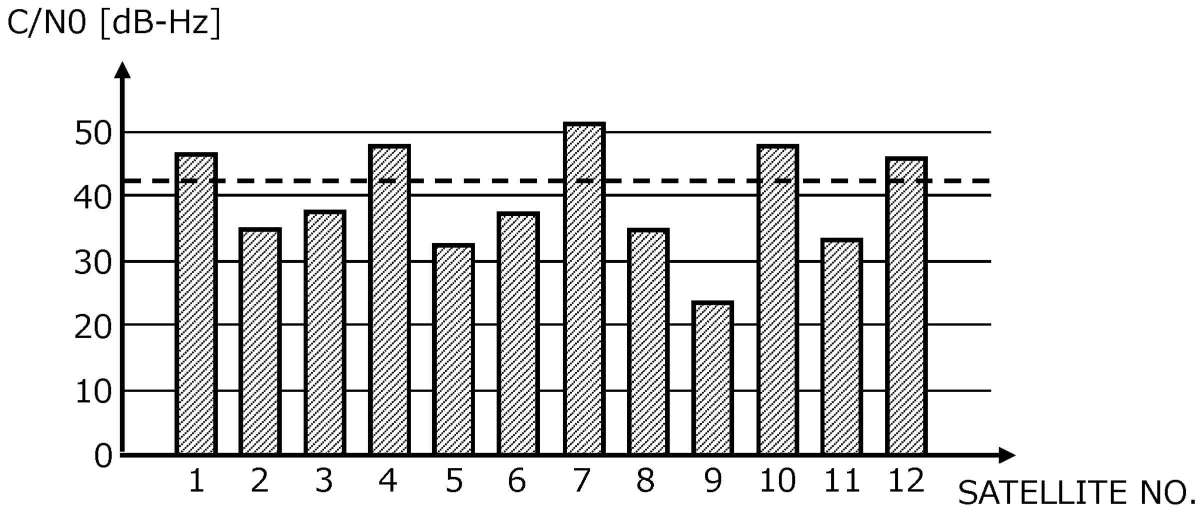


FIG. 22B

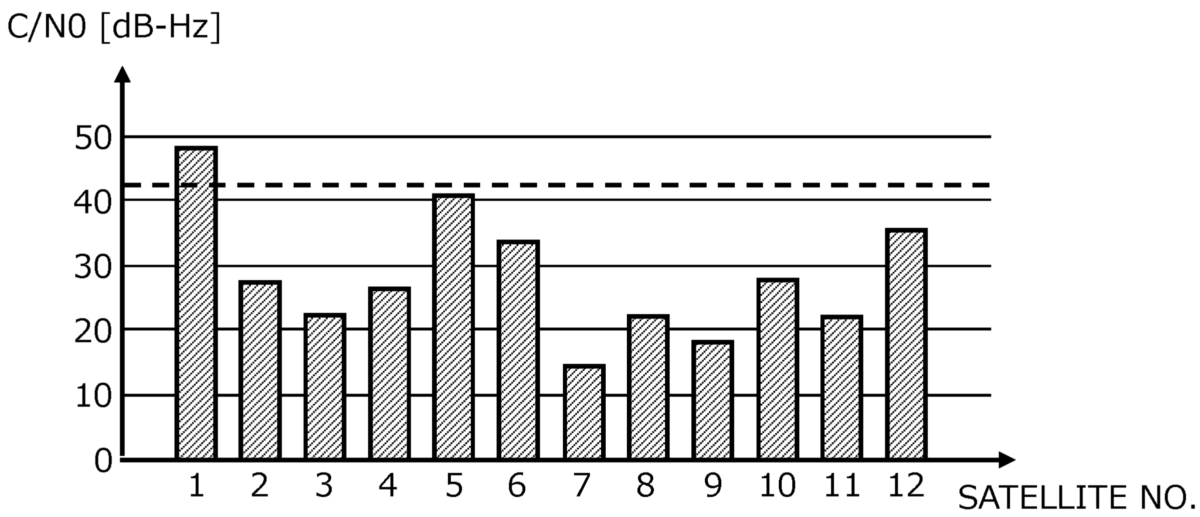


FIG. 23

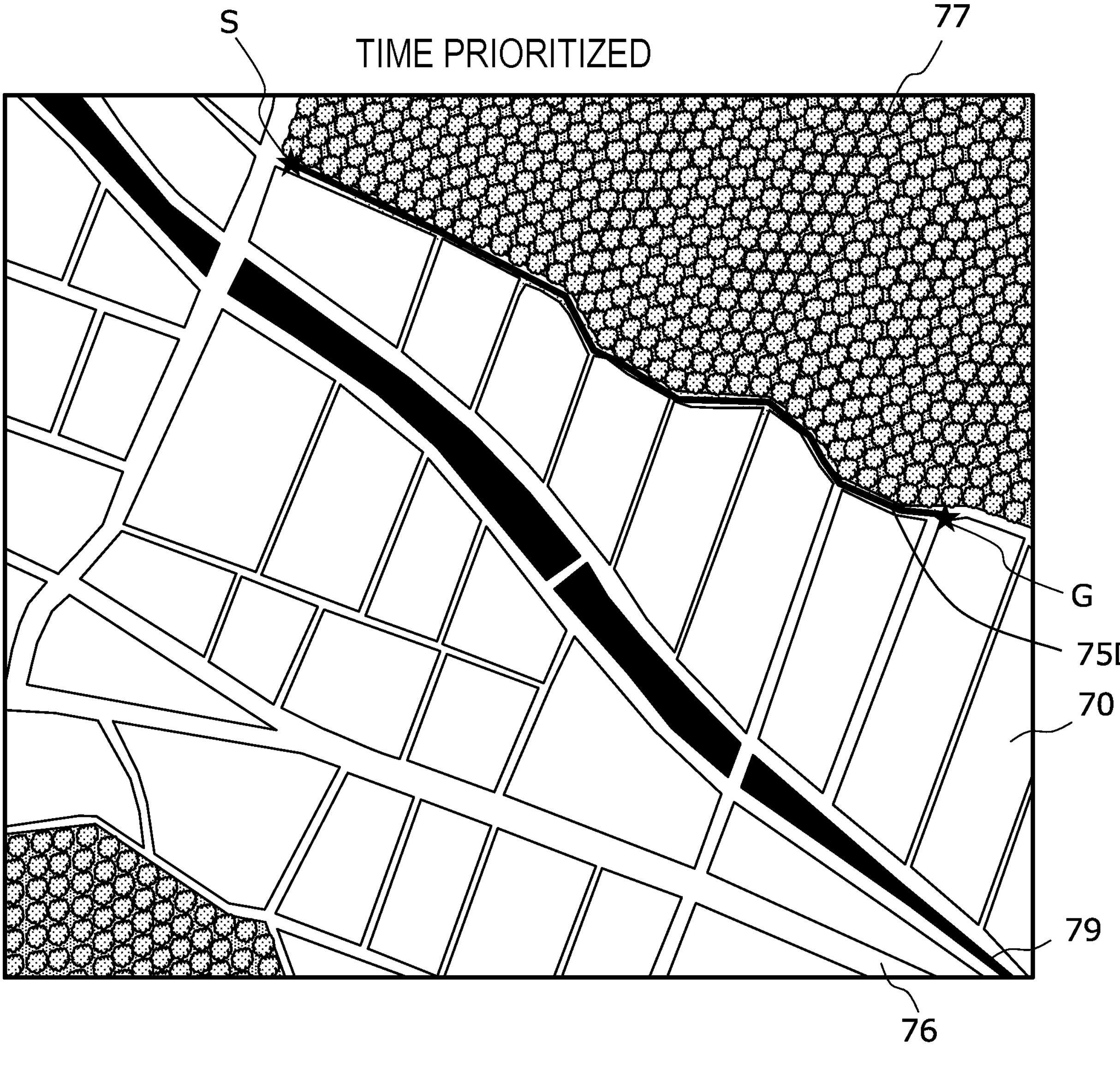


FIG. 24

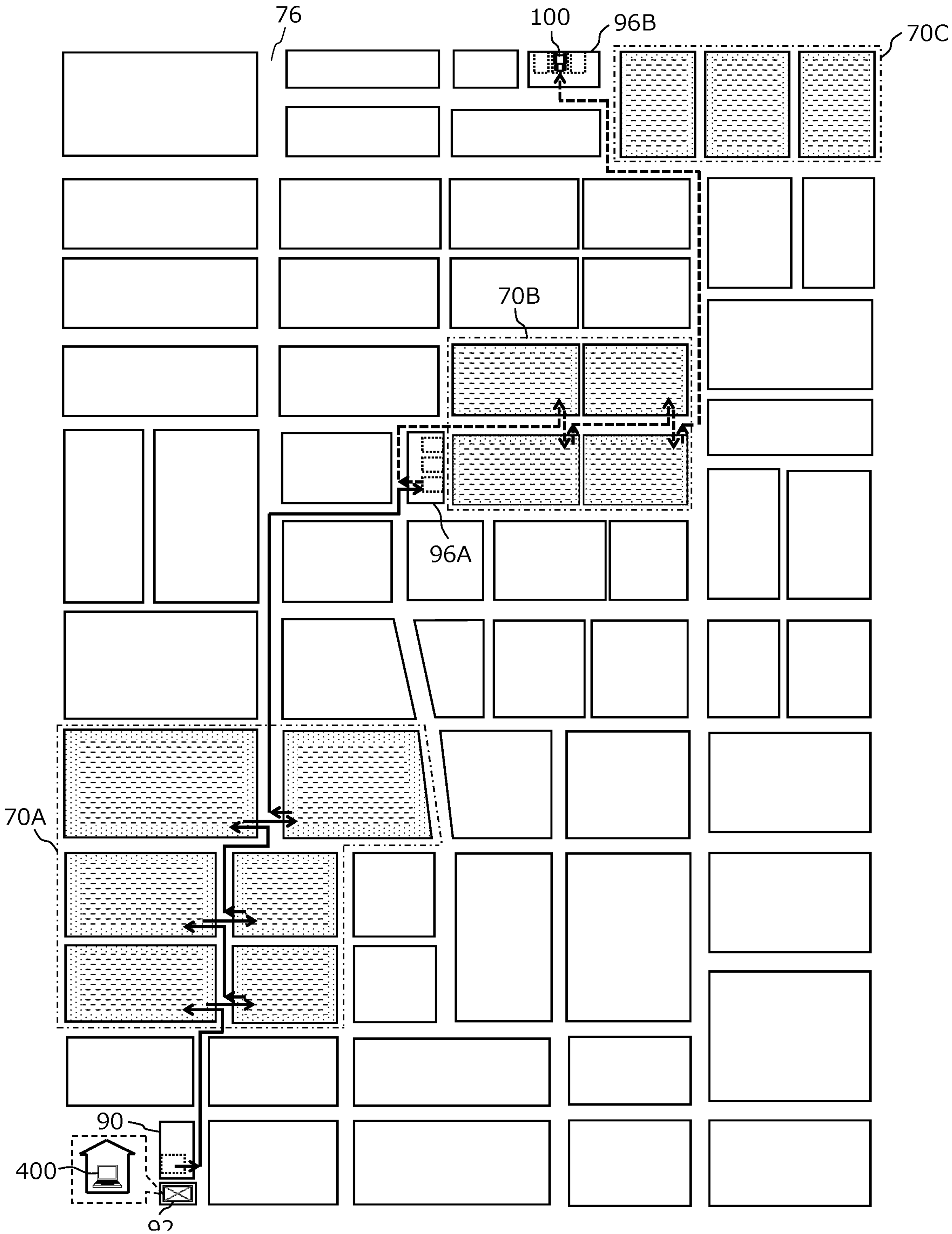


FIG. 25

FIELD	WAITING AREA
FIELD #1	WAITING ARE A
FIELD #2	
FIELD #3	
⋮	
FIELD #30	
FIELD #31	WAITING ARE B
FIELD #32	
FIELD #33	
⋮	
FIELD #60	
FIELD #61	WAITING ARE C
FIELD #62	
FIELD #63	
⋮	
FIELD #100	

FIG. 26

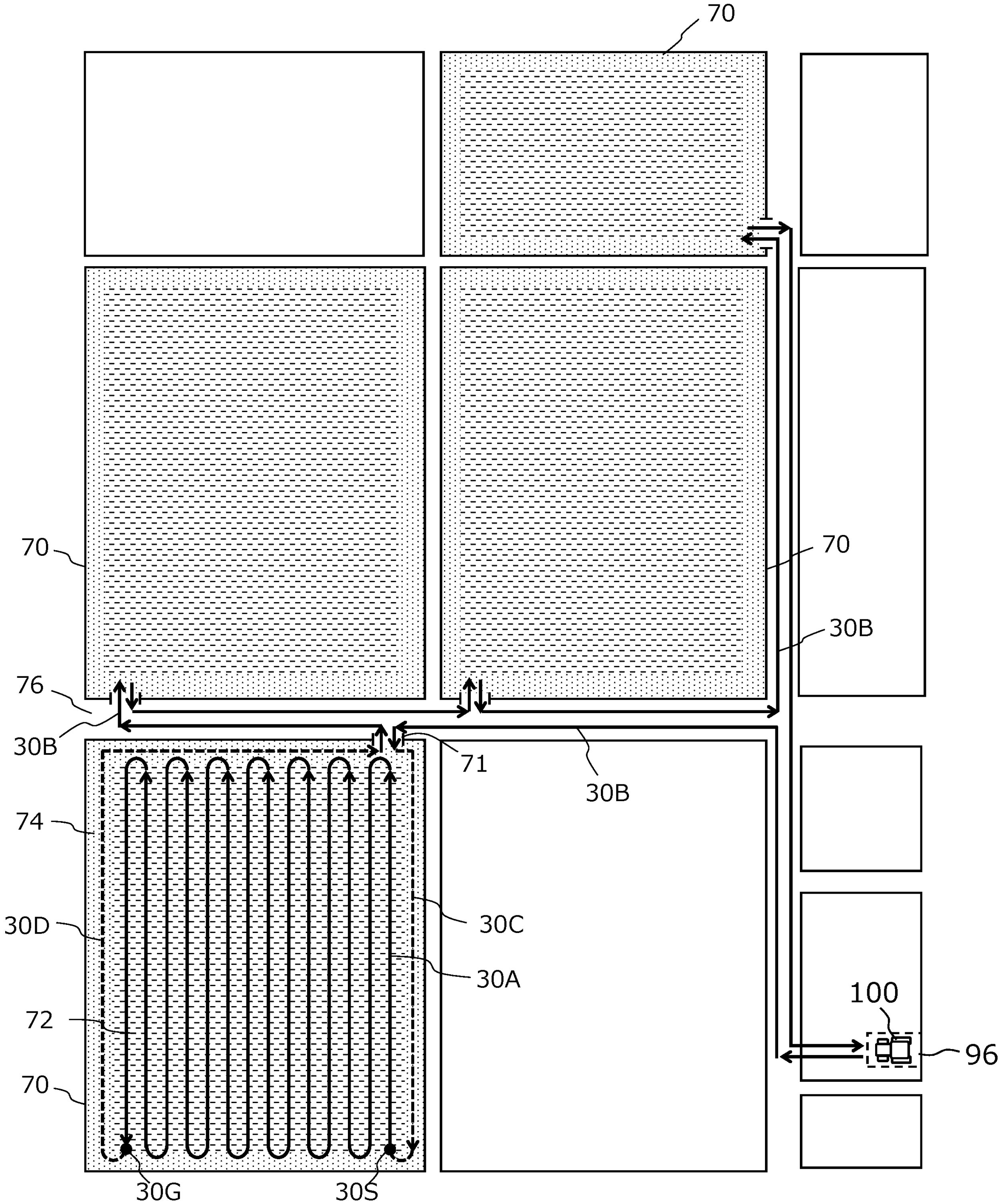


FIG. 27

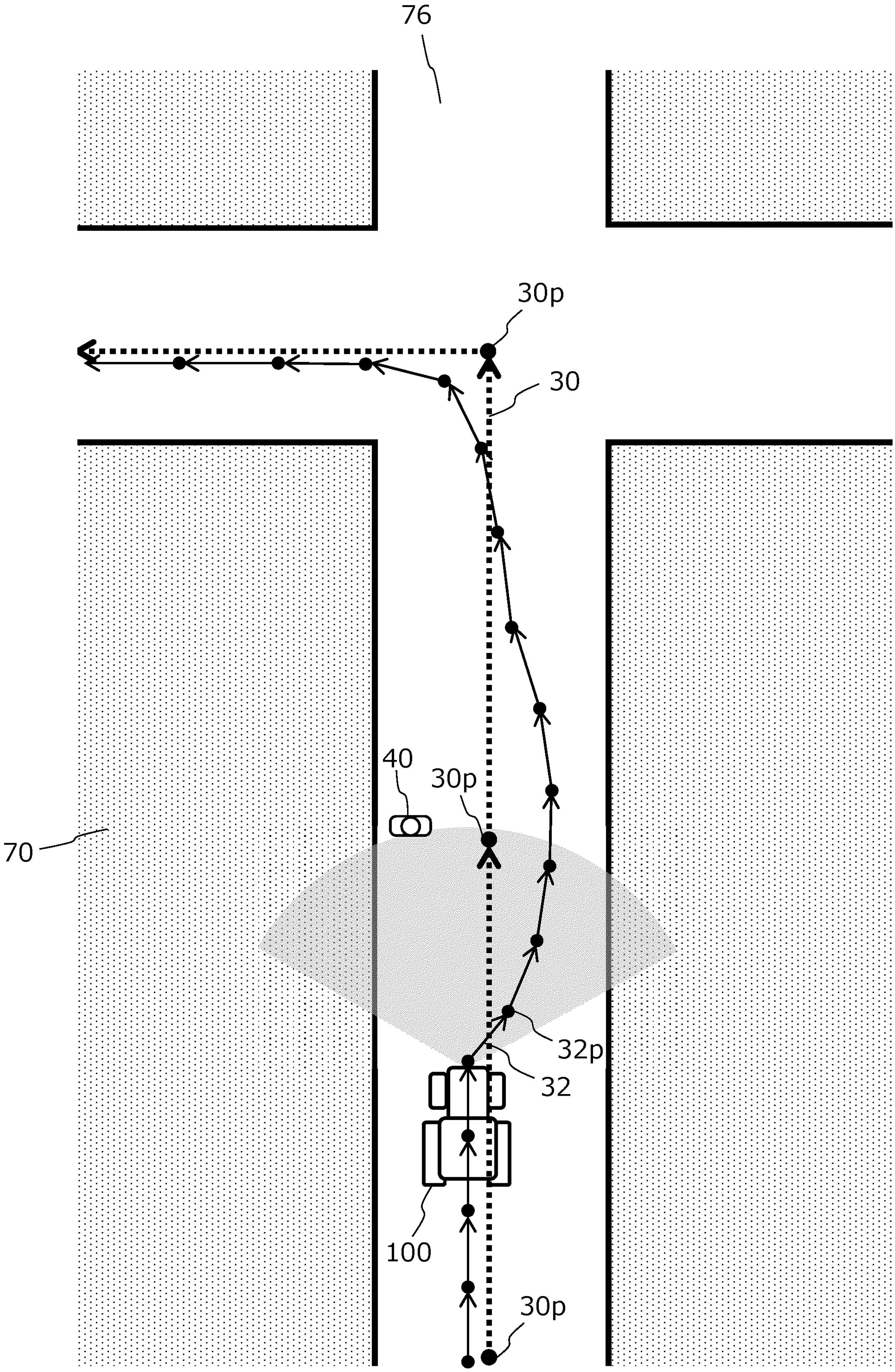
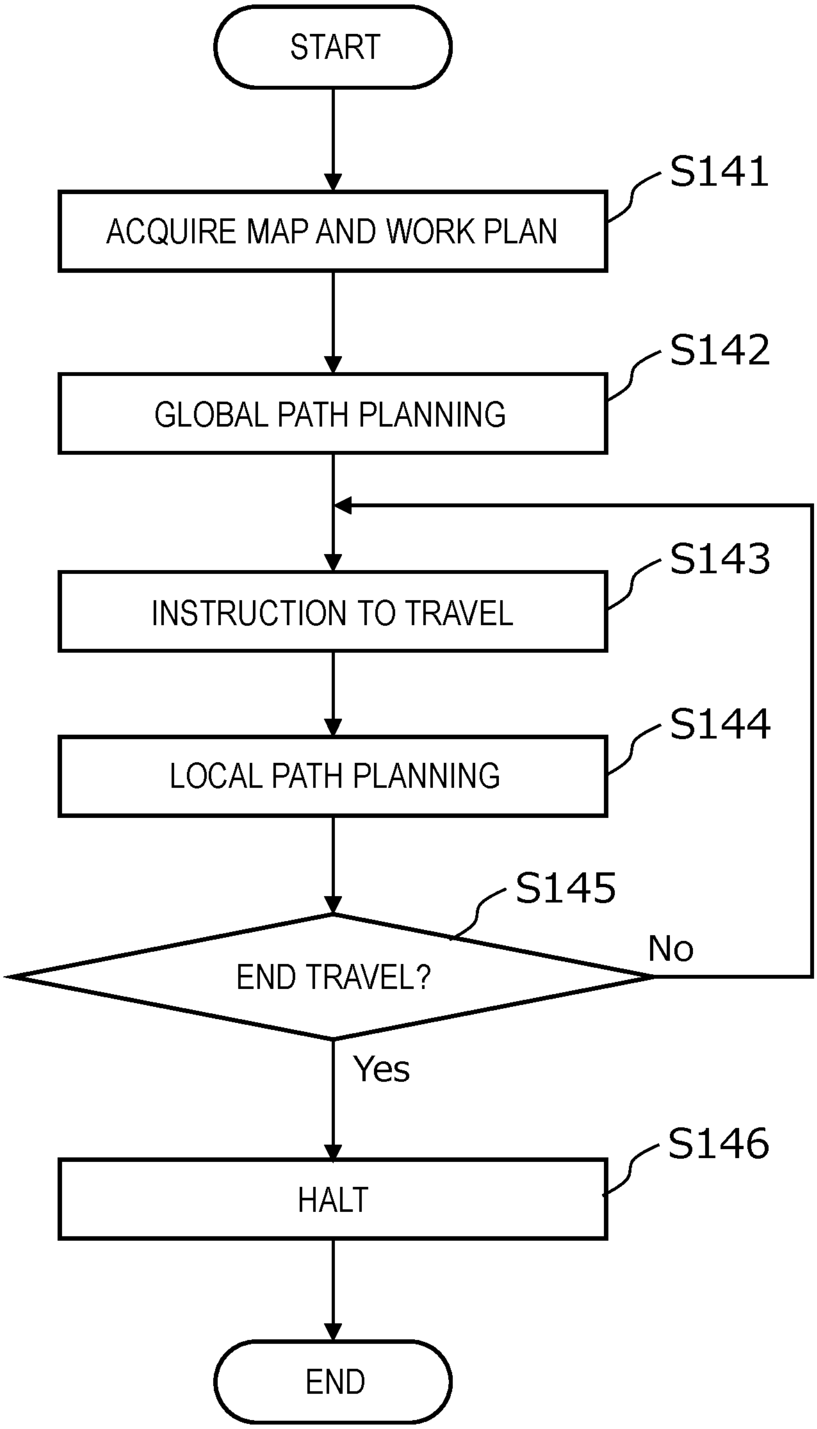


FIG. 28


START
S141
ACQUIRE MAP AND WORK PLAN
S142
GLOBAL PATH PLANNING
S143
INSTRUCTION TO TRAVEL
S144
LOCAL PATH PLANNING
S145
END TRAVEL?
No
Yes
S146
HALT
END

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/040395

A. CLASSIFICATION OF SUBJECT MATTER

A01B 69/00(2006.01)i; ***G05D 1/02***(2020.01)i
FI: A01B69/00 301; G05D1/02 N; A01B69/00 303F

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A01B69/00; G05D1/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2020-103092 A (KUBOTA CORP.) 09 July 2020 (2020-07-09) paragraphs [0046], [0050]	1, 11, 13
Y	paragraphs [0046], [0050], [0052], [0053], fig. 12A, 12B	2-13
Y	JP 2021-94030 A (GEOSURF CORP.) 24 June 2021 (2021-06-24) paragraph [0023]	2-13
Y	JP 2021-35381 A (KUBOTA CORP.) 04 March 2021 (2021-03-04) paragraph [0075]	10-13

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 January 2023	**17 January 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/040395

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2020-103092 A	09 July 2020	(Family: none)	
JP 2021-94030 A	24 June 2021	JP 2020-78334 A paragraph [0023]	
JP 2021-35381 A	04 March 2021	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2021073602 A **[0004]**
- JP 2021029218 A **[0004]**